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Section 74 Seafood Processing Study
Executive Summary. Appendix, Volume III

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16. ABSTRACT

Section 74 of the Clean Water Act of 1977 requires the Environmental Protection Agency (EPA) to investigate the ecological effects of seafood waste discharges and to identify treatment and waste utilization technologies applicable to seafood processing operations. As a result of this section of the Act this report was prepared and submitted to Congress.

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APPENDIX

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SECTION 74
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EXECUTIVE SUMMARY

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APPENDIX F

EPA SITE VISIT TO BRUNSWICK, GEORGIA SHRIMP PROCESSING FACILITY

I. General

On 2/12/79 an EPA representative visited the King Shrimp facility in Brunswick, GA. This facility produces breaded and non-breaded shrimp and discharges wastewater to the Brunswick River. The purpose of the visit was to document conditions at this facility and to meet with J.R. Duggan, the plant manager, and Dr. Wayne Bough, of the University of Georgia Marine Extension Service.

II. Wastewater Characteristics and Existing Waste Treatment

King Shrimp is a large facility that discharges approximately 360,000 gallons of wastewater per day. As for all shrimp processing operations, this water is high in biochemical oxygen demand (BOD) and suspended solids. Georgia water quality standards require that the dissolved oxygen (DO) levels of receiving waters be maintained at an average of 5 parts per million (ppm) and at a minimum of 4 ppm. In efforts to maintain the Brunswick River waters at this level, the Georgia Department of Environmental Protection (DEP) has required King Shrimp to treat its wastewater to achieve the equivalent of secondary treatment (85% BOD removal).

To achieve 85% BOD removal, King Shrimp has instituted dry clean-up techniques, screening of wastewaters and discharge of screened wastewater from the breading operation to the local POTW. This breading water comprises approximately 60,000 gallons per day which is one sixth of the total flow of the plant. In addition, the discharge outfall has recently been relocated from the relatively shallow ship slip near the plant to deeper water in the river.

The total capital investment needed to comply with the Georgia DEP requirements is estimated by Mr. Duggan at $175,000. POTW user charges amount to an additional $16,000 per year.

Receiving Water Effects

King Shrimp for many years discharged all wastes (including shells) to a ship slip on the Brunswick River near the plant. According to the Georgia DEP, this area receives little flushing and significant accumulations of shell occurred. The local health department received a number of complaints about the odors in this area at low tide. As noted above, this facility has recently achieved 85% BOD removal and, in addition, the discharge outfall has been relocated to a deeper part of the river where currents may better disperse the wastes. Although a portion of the buildup of wastes in the ship slip still remains, conditions have improved and fewer complaints have been received regarding this facility.

Other Information

Of major concern to King Shrimp are the Georgia water quality standards which require that waters be maintained with an average dissolved oxygen (DO) content of 5 ppm and a minimum of 4 ppm at any time. These standards are the basis of requiring secondary treatment (or the equivalent) for all point sources. The water quality-based treatment requirements are more stringent than the national technology based standards currently in effect for this industry. Currently, King Shrimp is the only major Georgia seafood processor that does not practice secondary treatment of its entire waste flow.

Mr. Duggan stated that these water quality standards as applied stringently to the discharge of seafood wastes are unfair. Mr. Bough indicated that, in his opinion, a minimum DO standard of 4 ppm is not suitable for coastal estuarine waters and that even in unpolluted pristine coastal waters the DO sometimes falls below 4 ppm. Mr. Duggan felt that Georgia's strict environmental policies have contributed to the economic decline of the seafood processing industry in this area; he indicated that other nearby states impose less stringent environmental controls on seafood processors.

The Georgia Department of Environmental Protection indicates that the water quality standards are necessary to protect the coastal waters which serve as spawning grounds for various harvestable species, including shrimp. Thus, the standards are viewed as necessary to protect the seafood industry.

G. A. Rhame

File

OBSERVATIONS ON THE DISPOSAL OF SHRIMP HEADS INTO SHEM CREEK, MT. PLEASANT, SOUTH CAROLINA

The writer was requested by the management of the Mt. Pleasant, S. C., Water and Sewer Commission (1) to make a study of the problems of shrimp head disposal from shrimp processing plants located on Shem Creek in Mt. Pleasant, South Carolina.

Shrimp processing plants within this area are devoted to the simple operation of heading, washing, grading and icing for distribution. There is no peeling, breading or canning on site. Heads are the most important component of waste, with some discards. Business is quite brisk in good years.

Summary and Conclusions

Disposal of shrimp heads from the Shem Creek processors by local waste treat plants, hauling to landfill, complete destruction or production of by-products would impose a crippling financial burden on the processors. There may be some future to the by-products system.

Disposal to the local city sewage treatment plant would cause a BOD overload. Dangers of health hazards and DO depletion from disposal to Shem Creek appear to be exaggerated. Care would be needed to prevent aesthetic objections. The present system of barging to a nearby harbor channel has worked well at moderate cost. It should be continued until problems connected with other possible systems are eliminated.

Analytical Studies

Some local shrimp heads were obtained and subjected to the BOD_5 determination in the laboratory of the Mt. Pleasant sewage treatment plant. Heads were weighed wet to avoid loss of volatile organic components, broken up in a household blender containing 1000 ml of

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distilled water. BOD_5 of the resulting mixture was determined according to Standard Methods (2). After a few unreasonably low results all incubation bottles were seeded with 0.5 ml of fresh settled sewage. DO was measured by the Sodium Azide-Winkler method. A number of runs were aborted for various reasons. Results are shown in Table 1. The results in Table I work out to 150 lbs. of BOD_5 per 1000 lbs. of shrimp heads.

A letter from John M. Knox of the South Carolins BHEC states that the department's laboratory at Charleston, S. C., found 170 lbs. of BOD_5 per 1000 lbs. of "shrimp or shrimp fragments". Most of the organic matter in shrimp is in the part used for food -- the tail.

Development Documents (4) for the EPA "Guidelines and Standards for Canned and Preserved Seafood" show that a considerable study was made, but none on operations like those at Mt. Pleasant. One operation showed a BOD_5 of 46 lbs. per 1000 lbs. of shrimp processed. (The only one where BOD was measured). The above shows a BOD-organic nitrogen ratio of 4.6/1. The ratio for "normal" sewage is considerably higher.

Quantity of Waste

Data obtained from the South Carolina Wildlife and Marine Resources Department is shown in table II. The figures in parentheses were calculated by the writer.

From table II it can be expected that on the basis of 25 working days per month, upwards of 8,000 lbs. of heads per day would be wasted and that this would represent about 35% of the weight of shrimp landed.

From the analytical data and table II it can be expected that a waste load of about 1,200 lbs. BOD_5 would be generated on a maximum operating day at Shem Creek.

Waste Disposal Alternatives

Disposal to Sewer

Sewers of the City of Mt. Pleasant Water and Sewer Commission are abailable to the Shem Creek processing plants and probably have adequate hydraulic capacity.

Previous experience with disposal to sewer has shown that shrimp heads rapidly clog sewers. The peculiar "prickly" shape of the heads probably caused them to ball up. Passage thru a grinder eased this problem. Shem Creek sewers discharge to the city's main plant, which has a capacity of 1.1 mgd. or about 11,000 lbs. BOD$_5$ /day.

The addition of 7,000 lbs. BOD$_5$ per day during the busy season would result in an unmanageable load. The effect of off-peak loads would not be good. If, by some presently impractical technical process the shrimp-head load could be discharged to the sewage treatment plant at a steady rate throughout the year there would still be an undesireable reduction in the allowable household connections.

Service charges for use of the system would presumably by set on an equivalent per-capita basis. Cost to the processors would be substantial.

Disposal by Private Treatment Plant

Development Documents for the EPA Guidelines (4) contain a considerable discussion of proposed methods of treating shrimp processing wastes from breading and canning plants.

Collina and Tenney (6) (7) present some interesting ideas on simplified analytical control of seafood processing waste treatment plants. A~~n~~ elaborate calibration process is required and might be useful for application to sewage treatment plant control.

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Brenninfield, Winn and Phillips (8) discuss seafood waste treatment (without reference to shrimp) and make a pertinent observation: "The wastewater treatment capital costs in almost all cases exceed the present capital investment in the processing plant and facilities". The combination of relatively high capital costs, seasonal operation, need for skilled operators and small areas of land available near shrimp processing plants would make local waste treatment systems a bankruptcy burden on processors.

Conversion to Salable By-Products or Complete Destruction

The S. C. Wildlife and Marine Resources Department (5) reported on a considerable study of the problems and economics of conversion to a salable by-product and complete destruct by incineration. Transportation to a regional conversion or destruction plant was an essential assumption of the study. This adds a substantial cost. The study presents no conclusions or recommendations, but the general attitude is not encouraging.

The EPA Development Document (4) describes on page 171 a waste screen built onto a hydraulic ram which compresses the screenings. This device greatly reduces the bulk and water content of the waste, which would reduce transportation cost and fuel needed for drying or incineration. Refrigeration while holding for transportation might become practical.

To the writer's knowledge the only by-products plant in the state is that of the Blue Channel Corporation at Port Royal, S. C. The system is used primarily for crab residues and is reported to have handled shrimp residues without difficulty. (Conversation with Will Lacey). (5)

Disposal to Landfill

This procedure was tried by the Shem Creek processors. Decomposition of the shrimp heads during accumulation and transportation generated highly unpleasant odors. Complaints led to stoppage of this practice. Compression and refrigeration of wastes during holding, if adequate refrigeration capacity is available, would improve this situation.

Disposal Into Shem Creek

Shem Creek is a small tidal estuary of the Charleston, S. C., harbor. Average tidal range is about 5 feet. The estuary is bridged by U. S. 17 (Coleman Blvd.) in Mt. Pleasant, S. C. That portion of the creek on the harbor side of the bridge has a dredged depth of 7 feet. It is narrow, bordered by shrimpers docks, mostly on the East side, and has a considerable salt marsh and a large tributary tidal drainage ditch on the West side.

The portion of the estuary on the landward side of U. S. 17 rapidly tapers off to very shallow depths at low tide and becomes very narrow. It is surrounded by a considerable area of lightly flooded salt marsh with tidal drainage ditches serving highly populated areas. Dry-weather inflow is negligible.

Attempts to sutdy disposal of shrimp heads into Shem Creek immediately ran into a frustrating situation - there is no data on water flow in and out of the creek.

The SC WMR and DHEC departments (9) made a joint study of this situation at a time when there were no shrimp heads or other formal effluents reaching the creek. Their results show a rapid dispersal of dye into the harbor. Some moved out of the creek in a very short time, some moved very slowly -- as usual. DO concentrations were

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normal for such a body of water in summer, averaging about 5.5 ppm. Unfortunately, their current meter malfunctioned.

The main channel between the bridge and the harbor was measured during the above effort. Dimensions found were:

Length - 5300 feet
Width - 150 feet
Depth - 12 feet at high tide
- 7 feet at low tide
Volume - 9.5×10^6 cubic ft. at high tide
- 5.0×10^6 cubic ft. at low tide
- 500×10^6 lbs. water at high tide

A rough tracing was made of both parts of the creek from an aerial photograph. The graph paper overlay method indicated that the area of channel and marsh on the landward side of the bridge was at least 25 times that of the channel on the harbor side of the bridge -- which would receive all of the shrimping waste. If the average flooding depth of the landward marsh is considered to be one inch (the marsh is very irregular) the total volume of water passing through the channel to the landward marsh would be 1/6 the volume of the channel. A complete tidal cycle in the Charleston area takes about 12.5 hours.

Estimation of oxygen consumption

Assume "standard" rate of demand exertion for lack of other data.

Ultimate BOD = 1.5 x BOD_5
$\text{BOD}_{0.5}$ = 0.11 x ultimate
= 0.11 x 1.5 x BOD_5
= 0.11 x 1.5 x 1200 lbs.
= 200 lbs. if all waste released in one tidal cycle
= $\frac{200}{500}$ = 0.4 ppm for channel volume

Demand would be less in practice since two shifts would last longer than one tidal cycle. Effects on DO from a peak day operation of 16 hours would be cyclical and minimal.

Possible health hazards were not evaluated for lack of data. Note that the creek is not well adapted to swimming or water skiing due to lack of access, narrow channels landward of the bridge and considerable shrimp boat traffic during warm weather in the dredged channel.

It appears possible that the unsightly appearnace of shrimp heads in the creek and marshes could be eliminated by grinding and underwater discharge. This would have to be verified by on-side experiment.

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Carl Dysinger, Project Officer, Food Industries Branch, EPA

Barbara A Bassuener, Manager of Public Affairs, WPCF

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(1) Mt. Pleasant Water and Sewer Commission, Mt. Pleasant, S. C., Ronald E. Bycroft, Manager

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TABLE I

Weight Shrimp Head - Grams	mgg BOD per L of Mixture		Grams per 1000 gr head
4.74	465		100
7.07	1100		153
4.85	660		136
9.27	1480		159
15.14	2600		170
7.66	1150		150
5.14	700		136
		Average	149

TABLE II
Monthly Landings of Shrimp at Shem Creek

1975

Month	Lbs. - Heads Off	Lbs. - Heads On	Lbs. - Heads	(5)
April	--	--	--	
May	94,010	144,859	50,849	(34)
June	192,061	305,917	113,849	(37)
July	208,798	357,306	148,508	(41)
August	126,834	199,667	72,833	(36)
September	234,913	362,149	127,235	(26)
October	196,331	302,350	106,019	(36)
November	110,595	170,317	59,722	(35)
December	83,912	129,224	45,312	(35)
1976				
April	3,422	5,270	1,848	(35)
May	107,364	165,728	58,364	(36)
June	213,906	340,013	126,107	(37)
July	319,322	512,726	193,404	(37)
August	183,206	286,717	103,511	(36)
September	207,787	320,487	112,700	(35)
October	156,073	240,353	84,280	(35)
November	196,262	302,242	105,980	(35)
December	13,919	19,895	6,976	(35)

Source: Fisheries Statistics Section, SCWMRD

(numbers in parentheses inserted by the writer)

SITE VISITS TO LOUISIANA SHRIMP CANNERIES

Calvin Dysinger, Project Officer

I. General

The Gulf Coast shrimp canning industry consists of approximately 15-20 canneries located along bays, rivers and bayous. In addition, a number of shrimp freezing and oyster processing operations are located in this area. EPA representatives visited several canneries during the period 11/8/78-11/9/78 to document existing waste treatment practices and visable aesthetic conditions resulting from waste discharges. Plant managers provided additional information.

The following facilities were visited:

Facility	Discharge Point
Violet Packing, Violet, LA	Mississippi River
Cutcher's Canning Co., Westwego, LA	Mississippi River
Robinson Canning Co., Westwego, LA	Mississippi River
Gulf Coast Packing, Dulac, LA	Grand Caillou Bayou
Grand Caillou Packing Plant, Dulac, LA	Grand Caillou Bayou

II. Process Description

Shrimps are caught along the continental shelf and are unloaded at receiving stations. The shrimp are packed into crates and trucked to the processing plants.

As the shrimp arrive at the plant, they are unloaded into a tank where shell, rocks and other debris are mechanically removed. The shrimp are transported into the plant by conveyor and are visually inspected to further remove debris. The shrimp are then mechanically sorted by size.

Processing consists of freezing or canning; some facilities operate both freezing and canning processes. Shrimp may be frozen either unpeeled or after peeling and may be breaded prior to freezing. Shrimp are also peeled prior to canning. The entire process of preparing peeled shrimp for canning consists of mechanical peeling, agitation (to remove pieces of shell), mechanical deveining (optional), steam cooking, grading for size, final inspection, filling the cans, addition of brine water, sealing and retorting.

III. Wastewater Characteristics

A Gulf Coast shrimp cannery generates approximately 100,000-250,000 gallons of wastewater per day. This water contains significant amounts of biochemical oxygen demanding wastes as solids or soluble material. The major sources of wastewater and solids are the peeling and deveining machines. In facilities where breading occurs, this operation generates additional biodegradable wastes.

IV. Existing Waste Treatment and Recovery Operations

In-Plant Controls

A large variation in waste management practices was observed at the facilities visited. As a portion of an EPA demonstration project, a considerable effort has been made in the Violet Packing facility to implement in-plant changes to reduce water use (with concurrent reduction in waste loads). These changes include replacement of flumes with dry conveyors and modification of valves and nozzles to decrease water use in cleaning the product and machinery. The other facilities, particularly those in the Dulac, LA area, were less sophisticated with regard to water conservation, and, generally, in efforts to minimize waste discharges.

End-of-Pipe Treatment and Waste Solids Handling

Violet Packing, Cutcher's Canning Co. and Robinson Canning Co. all operated screens to remove gross solids from their wastewaters. Both Violet Packing and Robinson Canning Co. also operate dryers which produce shrimp meal from the wet solids retained by the screen. The plant managers indicated that the market value of the meal was low and that the greatest advantage to meal production was to reduce the volume of solids requiring disposal. Cutcher's Canning Co. does not operate a dryer. The solids generated at this facility are mechanically partially dewatered (to reduce their volume) and hauled away to be used as fertilizer or to be landfilled.

The Gulf Coast Packing and Grand Caillou Packing facilities operate no end-of-pipe treatment. The plant managers indicated that there were no available means of disposal for screened solids. The local water table was too high to permit landfilling of seafood wastes.

V. Receiving Water Effects

Violet Packing Co., Cutcher's Canning and Robinson Canning Co. - These facilities discharge screened effluent to the Mississippi River. The particulates and soluble wastes discharged by these facilities did not have a readily apparent effect on this large body of receiving water. The potential exists for these discharges, in combination with other point sources, to impact both water quality and biota. A sampling program would be required to fully assess the impact on the benthic assemblages.

Gulf Coast Packing and Grand Caillou Packing Co. - These facilities discharge untreated wastes to the Grand Caillou bayou. Although this small, slow moving body of water has been classified as water quality limited by the state of Louisiana, these plants have been allowed to discharge their wastes without treatment because of difficulty in disposing of screened solids. According to the plant managers, these facilities will eventually receive municipal treatment upon completion of construction of a local treatment works.

The receiving water in the vicinity of these facilities appeared very stagnant and murky. It appears that the water movement in the bayou is insufficient to disperse the untreated discharge by these plants. The surface waters appeared oily and foamy.

VI. Other Information

A major problem for the shrimp industry in this area is solids disposal. Conventional solids recovery techniques (i.e. shrimp meal production) are not generally profitable in this region. The market demand for this low protein meal is quite low. Industry representatives recognize the need to conduct research on alternative solids recovery technologies, but they indicate that the industry has insufficient money to devote to such work.

The canners contend that pollution control requirements beyond screening (such as dissolved and flotation) are environmentally unnecessary and are overly expensive for the industry. They estimate that installation of DAF treatment will result in a net price increase of five percent per case of shrimp produced.

EPA Site Visit to Southern Florida Seafood Processing Facilities

I. General

There are a large number of small seafood processing plants located in southern Florida along the keys. The major commodity processed in this area is shrimp, with lesser amounts of lobster, crab and finfish. During 2/15/79 - 2/17/79 an EPA representative visited several processing plants located on Key West and Stock Island. The Florida Department of Environmental Regulation Marathon Office provided additional information.

The following plants were visited:

Singleton Packing Corp., Key West

Singleton Packing Corp., Stock Island

Coral Shrimp Co., Stock Island

King Shrimp Co., Stock Island

Morgan Shrimp Packers, Stock Island

Key Tex Shrimp Inc., Stock Island

II. Process Description and Waste Characteristics

Shrimp arrive at the plants by boat. The heads are removed at the plant and the shrimp may be manually or mechanically peeled before packing. No canning is done at the plants in this area; seafood commodities are either frozen or packed in ice for shipping.

Shrimp heads and shells constitute the major source of waste solids generated by these facilities. Total pounds of waste (as shrimp heads) generated per year has been estimated for some of these facilities. The following information is supplied by the Florida Department of Environmental Regulation.

Facility	lb/year shrimp heads discharged
Singleton Packing, Stock Island	315,000
Coral Shrimp Co., Stock Island	20,000
King Shrimp Co., Stock Island	20,000
Morgan Shrimp Packers, Stock Island	100,000
Key Tex Shrimp Inc., Stock Island	15,000

All wastes are currently discharged without treatment at these facilities.

III. Receiving Water Conditions

The coastal waters around Key West and Stock Island are polluted by a number of different sources including sewage plants, power plants and commerical and private boats in addition to the seafood waste discharges. The surface waters near the seafood plant discharge points appeared murky and oily with bits of floating debris. Although the seafood discharges are not wholly responsible for the conditions in the harbor, they appear to be contributing to degradation of these waters.

EPA Seafood Study-Site Visits to Maine Sardine Canneries

I. General

The Maine sardine canning industry consists of 15 canneries found at various locations on or near the Maine coast including bays, inlets and estuaries. As part of the Section 74 Study, I visited a number of processing locations during the period 10/17/78-10/20/78 to document existing waste treatment practices and visible aesthetic effects resulting from the waste discharges. In addition, I discussed these and other issues with various plant managers and with a representative of the Maine Department of Environmental Protection.

purpose

The following facilities were visited:

Facility	Discharge Point
Stinson Canning Co., Bath, ME	Kennebec River
Holmes Packing, Rockland, ME	Rockland Harbor
North Lubec Canning Co., Rockland, ME	Rockland Harbor
Port Clyde Packing, Rockland, ME	Rockland Harbor
Stinson Canning Co., Prospect Harbor, ME	Prospect Harbor
Sea-pro, Rockland, ME (reduction facility)	

II. Process Description

Sardines arrive at the processing facility either by boat or by truck. The fish may be pumped to storage bins or may be processed directly. These storage bins contain refrigerated brine (a salt solution) to preserve the fish until they are processed. Within the plant, fish (and waste) are transported to and from the processing tables either by flumes or by conveyors. Conveyor systems minimize water contact and thus generate less waste than the fluming systems.

Processing generally consists of removing heads and tails, packing into cans, precooking, addition of packing oils or sauces, sealing the cans, retorting and cooling. Most of these steps generate waste of various types. Cans are packed manually. In some cases, steaking machines are used to cut the tail sections into small pieces, which are then manually packed into cans. Precooking occurs before the cans are sealed. This operation partially cooks the sardines and removes undesirable fish oils. Packing sauces or oils are added automatically by the sealing machine. The subsequent washing process removes any waste or oils which may adhere to the cans. The cans are then automatically loaded into the retort, where the final cooking process is completed at 235°F for one hour. Finally, the cans are water cooled, washed again and packed into cases.

III. Wastewater Characteristics

Sardine canneries are characterized by a relatively low wastewater flow (10,000-20,000 gallons per day). However, these facilities generate significant amounts of biochemical oxygen demanding wastes (BOD), suspended solids and especially grease and oil. Specific processes which contribute a large portion of the waste are head and tail removal (or steaking) and the steam precook operation, which is a major source of fish oil.

IV. Existing Waste Treatment and Recovery Operations

Generally, between 40 and 60 percent of the raw sardine product is actually canned as a final product. The remaining 40-60 percent consists of waste - heads, tails, meat and oil. A significant amount of this waste is recovered and is not discharged to the local receiving waters.

The major means of waste collection observed in these facilities are as follows:

(1) Dry collection of heads and tails in the plant before they enter the waste stream.

(2) Use of rotary or tangential screens to remove small particles of waste from the waste stream.

(3) Use of oil separator units to recover oil from the steam cook process water.

Solids generated by screening are either sold to local lobstermen as bait or sold to a reduction facility (i.e. Sea-pro) where they are processed into fish meal and oil. Fish oil collected from the oil separator units is also sold to the reduction facility for purification.

At several facilities, a portion of the waste stream is segregated and pumped to the local municipal system. This generally includes only the fresh (non-saline) water such as the steam cook water (after oil separation) and the sanitary waste water. This fresh water constitutes only about 5 percent of the total waste streams for a typical facility; the remaining 95 percent of the waste stream (mostly salt water) is discharged directly (after screening to remove solids).

Although the existing waste collection technologies (screens and oil separators) are quite simple in concept, some of the plant managers reported problems in practical operation of this equipment. Most notably, one facility's screen required nearly continuous cleaning to prevent clogging.

Additional information regarding waste recovery processes is presented in the technology and waste handling sections of this report.

V. Receiving Water Effects

no [illegible]

Although previous EPA work has characterized the sardine cannery effluent discharges in some detail, no formal ecological effect studies have been done along the Maine coast to determine the impact of these effluent discharges on the receiving waters. Hence, the information presented here is limited to observations and information supplied by industry and Maine Department of Environmental Protection (DEP) personnel.

Stinson Canning Co., Bath, Me - This facility discharges screened wastewater directly to the Kennebec River (excluding cooker water, which is sent to the local treatment plant). The outfall discharges under a dock along the shore of the river where some pieces of waste up to 1/2" could be seen. However, most of the waste particles were very fine and were mixed with air bubbles introduced by the discharge pump. At high tide, when the water was relatively slack, the cannery discharge produced a visible discoloration of the river water extending about thirty feet from shore with some oil visible on the surface of the river. In contrast, during the outward tidal flow, the wastewater discharge was rapidly dispersed. The plant manager indicated that the discoloration from the discharge was due to the air bubbles pumped out with the wastewater and that this problem could be solved through installation of a wastewater holding tank and extension of the outfall. He further reported that he had received no complaints from the surrounding community regarding the effluent discharge.

Holmes Packing, North Lubec Canning Co., and Port Clyde Packing, Rockland, ME - These facilities (along with several local freezing facilities) discharge screened effluent to Rockland Harbor (excluding cooker water, wash down and can wash water which are sent to the municipal treatment works). Although relatively little processing was occurring at these facilities during the visit, a small amount of oil was visible on the surface of the harbor (near the discharge points).

The plant managers of these facilities feel strongly that the present level of treatment (screening with oil separation) is more than adequate to protect the environment from adverse effects. They indicated that since the implementation of screening and oil separation there has been less visible grease on the surface of the harbor near the canneries. However, the plant managers also stated that the removal of these wastes (with their nutrients) resulted in fewer fish and lobster in the area. They further indicated that the twelve foot tides at Rockland prevented any accumulation of wastes in the harbor.

Maine DEP personnel indicated that the canners have caused some environmental problems in Rockland Harbor. Most notably, there are reports of seagulls being coated with oil (floating on the surface) and drowning. In addition, there have been some complaints about the oil which tends to coat rocks and adhere to boats in the area.

Stinson Canning Co., Prospect Harbor - This facility is located in a more remote area than the other sites visited. Most of the process wastewater passes through a screen and is discharged directly. The outfall extends about forty feet from shore and discharges the effluent into a depth at low water of ten feet. At this facility, the cooker water is not pumped to a municipal treatment works; rather, this waste stream passes through an oil separator and is discharged directly, resulting in a greater discharge of fish oil than at the other plants visited. The Maine DEP has documented problems due to the floating oil in Prospect Harbor. This cannery has installed a boom on the surface of the harbor above the outfall as a means to help contain the fish oil floating on the surface. The plant manager indicated that, since the installation of the boom, they had received substantially fewer complaints about the oil.

VI. Other information

The Maine DEP reports that the installation of screens and oil separator units has resulted in improved water quality and aesthetics. The major remaining problem is the floating fish oil which is not always dissipated by currents and tidal movements. Existing oil separator units treat only the highly oily cooker water; the oil generated by other processes in the plant is not currently removed. Technically, it appears that the application of air flotation would substantially decrease the amount of oil discharged by the canneries.

APPENDIX G

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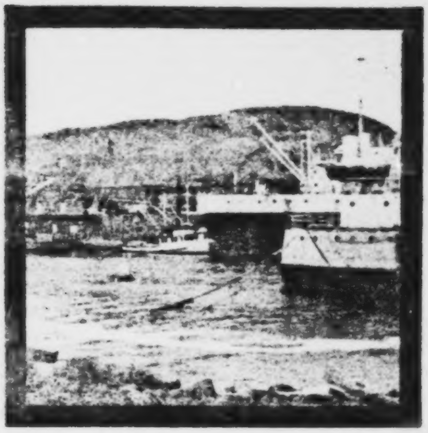
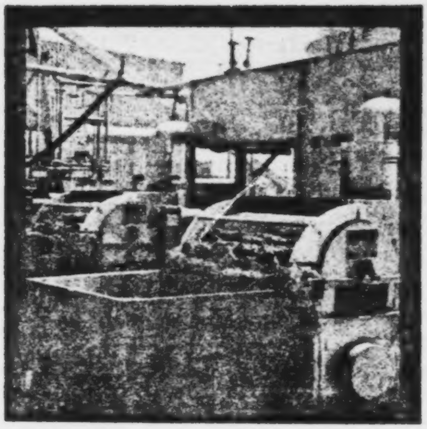
TECHNOLOGY FOR SEAFOOD PROCESSING WASTE TREATMENT AND UTILIZATION

SECTION 74
SEAFOOD PROCESSING STUDY





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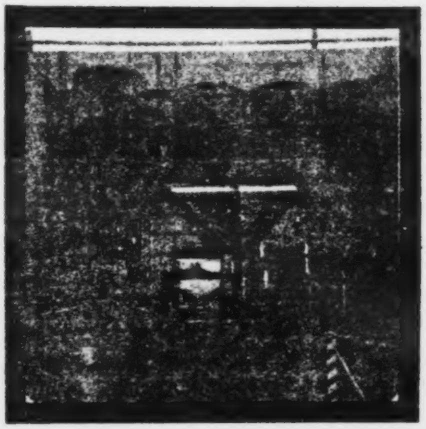

BY THE
EDWARD C. JORDAN CO., INC.
PORTLAND, MAINE
CONTRACT NO. 68-01-4931

MARCH 1980

ENGINEERING
PLANNING
ARCHITECTURE

Edward C. Jordan Co., Inc.

P.O. Box 7050, Downtown Station • Portland, Maine 04112
Telephone: 207-775-5401 TELEX: 94-4329

2983-10
(SL 2.51)

March 3, 1980

Mr. Calvin J. Dysinger
Effluent Guidelines Division (WH-552)
U.S. Environmental Protection Agency
Waterside Mall - East Tower
401 M. Street, S.W.
Washington, DC 20460

Dear Cal:

Subject: Final Report
Section 74 Seafood Processing Study
Contract No. 68-01-5772

Enclosed please find our final report entitled "Technology for Seafood Processing Waste Treatment and Utilization" which is the Jordan Company's written contribution to the Section 74 Seafood Processing Study. This document reflects the industry comments which were based on the draft final report and submitted to EPA on April 17, 1979. The draft version of the report was prepared under EPA Contract No. 68-01-4931.

In accordance with Work Order No. 10, Jordan Company personnel will be available for consultation until completion of the Section 74 study. If you have any specific questions concerning this document or require further assistance, please feel free to contact me.

Sincerely yours,

EDWARD C. JORDAN CO., INC.

David B. Ertz

David B. Ertz, P.E.
Technical Project Director

DBE/msh

Enclosure

TECHNOLOGY FOR
SEAFOOD PROCESSING WASTE
TREATMENT AND UTILIZATION

FOR THE

SECTION 74 SEAFOOD PROCESSING STUDY

Prepared For

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EFFLUENT GUIDELINES DIVISION
WASHINGTON, D.C. 20460

By

EDWARD C. JORDAN CO., INC.
P.O. BOX 7050
PORTLAND, MAINE

CONTRACT NO. 68-01-5772

MARCH 1980

ABSTRACT

Section 74 of the Clean Water Act requires that the United States Environmental Protection Agency evaluate and report to Congress the effects of seafood processes which discharge untreated natural wastes into marine waters. To help meet that requirement, this report identifies and describes in-plant waste management techniques and end-of-pipe wastewater treatment technologies which are applicable to the seafood industry's pollution control efforts. Also described are secondary product and byproduct manufacturing options and solid waste handling and disposal methods which can help the industry better utilize or more acceptably dispose of its waste materials.

The seafood industry consists of many small-scale, seasonal operations which intermittently catch and process various fish species. For most of the industry, existing waste management practices are relatively simple, resulting in the wasting of a significant portion of the raw material brought to shore. Removal of a significant portion of this material will depend on developing potential markets for new byproducts. More complete resource utilization is possible through continued research efforts in this area. Development of byproduct markets can afford the opportunity for improved utilization of proteinaceous materials and concurrently reduce waste volumes and associated environmental control costs.

Some of the larger, year-round seafood processors, such as the large tuna canneries and major fish meal plants, practice more diversified waste management and environmental control methods. These include effective controls on water use, water recycling techniques, and better recovery and use of raw materials not incorporated as part of a human food (primary) product line. Wastes can be turned into secondary products suitable for human consumption, such as fish sticks, or they can be processed into byproducts such as petfoods, meal commodities, and related proteinaceous or nutrient-rich materials.

Some materials discarded as wastes cannot be converted into useful products. Improved waste treatment and disposal methods are required to reduce the quantity of these wastes that enter the environment. The seafood processing industry can apply a number of wastewater treatment and solids handling technologies to reduce waste discharges. Some of the most applicable technologies are wastewater screening, biological treatment and dissolved air flotation (DAF) in addition to, or in conjunction with, in-plant modifications to reduce the amount of wastes requiring treatment. Other, more advanced, technologies are available but do not appear widely applicable to the industry.

To reduce the quantity of wastes entering the environment, the seafood industry should improve its water and waste management practices, expand its efforts in the area of secondary product and byproduct manufacturing, and incorporate applicable wastewater treatment and solids disposal technologies. All of these methods have application within the seafood processing industry.

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ACKNOWLEDGEMENTS

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The direction and input provided by Calvin J. Dysinger, EPA Project Officer for this study, is acknowledged.

The Jordan Company wishes to thank the industry members, trade associations, equipment manufacturers and suppliers, and Sea Grant institutions which provided information during the conduction of this study. Specifically, the cooperation and assistance of National Food Processors Association, especially Jack L. Cooper who coordinated the preparation of industry comments regarding this report, is acknowledged. Significant contributions were also made by William R. Schnell of Velsicol Chemical Corporation; Peter M. Perceval of CHI-AM International, Inc.; E. Lee Johnson of Food Chemicals and Research Laboratories, Inc.; James Bray of Washington Sea Grant; Fredric M. Husby of the University of Alaska; and George Snyder and O.A. Clemens of Dravo Corporation.

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CHAPTER 1

INTRODUCTION

I. BACKGROUND

On December 27, 1977, the Clean Water Act of 1977 (PL 95-217) was adopted to amend several provisions of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). Section 74 of the new Act requires the U.S. Environmental Protection Agency (EPA) to conduct a study to determine the effects of seafood processes which dispose of untreated natural wastes into marine waters. Investigations must address the geographical, hydrological and biological characteristics of such waters. In addition, technologies to facilitate the use of nutrients in these wastes or to reduce their discharge into the marine environment must be examined. The findings of these investigations are to be reported to Congress.

II. SCOPE OF EFFORT

As part of the overall Section 74 study, a work program was developed to identify and assess the applicability of various technologies for byproduct manufacturing, in-plant waste control, wastewater treatment, and solids handling and disposal within the seafood processing industry.

Developing costs associated with achieving waste reductions through in-house management and end-of-pipe treatment were also to be considered during this effort.(126) The work program emphasized the utilization of seafood processing wastes for human consumption and the manufacturing of byproducts such as fish meal, fish oil and chitin/chitosan. While fish meal and fish oil have established markets, the widespread use of chitin/chitosan is subject to economic and regulatory constraints. For byproducts which have not been accepted for animal consumption the regulatory constraints were addressed. The economics relating to these manufactured byproducts, as well as their marketability, are part of the investigations undertaken by another contractor, Development Planning and Research Associates, Inc. (DPRA) of Manhattan, Kansas. To assist in the market feasibility effort, background information was developed regarding the technical aspects and the costs of installing and operating byproduct facilities.

This report addresses: 1) the control of seafood processing waste discharges, and 2) the current and potential uses of the materials eliminated from plant effluents. Discussions relating to disposal alternatives and waste utilization within the contiguous states also pertain to Hawaii, Puerto Rico, Guam, and American Samoa. Other study participants are assessing water quality impacts at various geographical locations and determining the market feasibility of certain byproducts manufactured from seafood wastes.

III. GENERAL APPROACH TO TECHNOLOGY ASSESSMENT FOR SECTION 74

This report presents information assembled for earlier development of effluent limitations guidelines for the seafood industry and supplemented with more recent information collected and analyzed to specifically fulfill the requirements of Section 74. Continuing with the approach established during the guidelines work, the general characteristics of the industry have been considered during this effort. The major areas of interest have been: 1) applicable waste control and treatment technology; and 2) utilization and disposal of seafood wastes resulting from the implementation of control technology. More specific information regarding the generation and character of seafood processing wastes and the methods available for its control and utilization can be found in the development documents (42, 43) and the draft report prepared for the reassessment of effluent guidelines for the industry.(126)

Foreign and domestic sources of information were identified through manual and computerized literature searches. Data which appeared pertinent to the Section 74 study was requested; all information received was reviewed and categorized for summarization in this report.

Technology deemed to be readily applicable to the seafood processing industry was emphasized during the evaluation process. In-plant control and end-of-pipe treatment costs have been updated during this effort. Conventional byproduct manufacturing which includes the production of meal and oil commodities has been addressed for selected areas of Alaska and the contiguous United States. More innovative techniques for utilizing seafood processing wastes have also received attention.

CHAPTER 2

SUMMARY AND CONCLUSIONS

This report addresses two of the major topic areas relating to the Section 74 seafood processing study:

1. waste control technology and the costs associated with reducing seafood waste discharges; and

2. utilization and disposal of materials incurred through the application of waste control technology.

These topic areas are examined to indicate existing practices and characteristics of the seafood industry, as well as potential ways for the industry to achieve further reductions in waste discharges to the marine environment. In some cases, technologies which have not been widely used by the U.S. seafood processors in the United States have been evaluated based on their application in foreign countries or within related food processing industries.

I. NATURE OF THE INDUSTRY

Because they have characteristics which are fundamentally different from the remainder of the industry, the tuna processing segment and modern fish meal plants (with solubles) should be assessed separately with respect to waste control and utilization. Many of the major tuna processors and modern fish meal plants practice on-site byproduct recovery at levels of sophistication which are significantly higher than much of the rest of the seafood industry. Through such practices, wastes entering treatment facilities or marine waters are minimized. Major tuna processors currently have in-place, the highest level of wastewater treatment employed by the industry.

Seafood processors comprising the remaining segments of the industry are generally small, seasonal operations, often family-owned. Most are labor-intensive or operate antiquated processing equipment and demonstrate limited and unsophisticated waste management techniques when compared to the tuna processing industry.

The significance of the waste loads which are generated by the seafood processors has been recognized by EPA during its previous investigations.(29, 75, 118, 145) The impact of waste discharges from this industry has been documented at several sites.(29, 75, 118, 145) Under the provisions of Section 74 of the Clean Water Act of 1977, recent data has been collected and analyzed to develop an up-to-date summary of the industry's current practices and the potential for improving waste management and raw material utilization.

II. WASTE CONTROL AND TREATMENT

A. Tuna and Modern Fish Meal Processing

Major tuna canneries and modern fish meal facilities exemplify the concept of total raw material utilization for the seafood industry. Extensive efforts are made by tuna processors to collect materials which cannot be used for human consumption for byproduct recovery. Some canneries recycle tuna thaw water, which is the largest single source of wastewater in the plant, to significantly reduce the volume of wastewater requiring treatment.

Fish meal facilities have employed the recycle approach for unloading raw material from boats. In some cases, a pneumatic system has been installed which only requires a small amount of water for operation. Unloading water is usually combined with stickwater and washwaters for the production of solubles as a byproduct. When recycling is practiced, condenser water and low-contamination condensate represent the largest volume of water discharged to receiving waters. Because these streams have such low levels of contamination, they are discharged directly (without treatment) to receiving waters.

The installation of thaw water recycle systems at canneries less advanced than some within the industry and the reduction of water consumption in other areas are future considerations for additional in-plant management in tuna processing segments. For end-of-pipe treatment, the optimization of in-place DAF systems is in order. Some consideration should also be given to biological treatment systems as a treatment alternative. Wastes from the tuna industry have been shown to be treatable by biological systems, as demonstrated by the Terminal Island, California municipal treatment plant. Effective treatment would be realized since the tuna industry processes essentially year-round; however, land requirements of such systems could be prohibitive for some canners.

Containing spills and reducing water use during washdown are pertinent to modern fish meal facilities. Pollutant levels in the resulting waste stream are not great enough to warrant treatment.

Facilities which do not now have the capability to evaporate the soluble streams (stickwater and bailwater) can provide the necessary equipment to do so, or employ barging for deep sea disposal as an alternative.

B. Other Industry Segments

Although processing activities vary among the remaining segments of the seafood industry, the general approach to proper waste management and its inherent benefits remains the same. The most effective means to reduce waste discharges from this portion of the industry would be for processors to generally upgrade, where possible, in-plant operations to control water use, minimize water contamination, and reduce the wasting of raw materials. A program employing such measures has a number of direct and immediate advantages:

- reduced water consumption, resulting in cost reductions;
- reduced waste loadings, resulting in lower environmental control costs; and

- o improved potential for more complete raw material utilization, including the manufacturing of marketable secondary products and by-products.

It is important to recognize that reduced water consumption does not result in a proportional reduction in waste loadings. Rather, when water is recycled and used only where necessary, the waste constituents become concentrated in the liquid waste streams. The reduced volume and higher concentrations facilitate treatment.

The economic incentives for more effective in-plant waste management are matched by a growing concern for improved environmental protection on the part of the industry. Processors in the segments of the seafood industry other than tuna and fish meal, generally have only screening (a simple technology) in-place. An updated approach to waste control emphasizes simple physical-chemical treatment methods (such as DAF) in conjunction with in-plant measures for most industry segments. This suggests that most operations generating relatively high wastewater flows and loadings can upgrade their wastewater treatment practices to achieve additional reductions. However, the cost of these improvements require consideration for any operation.

For plants which generate low waste flows from manual operations, effective controls include in-plant waste management practices followed by screening. Examples of such operations include hand-filleting bottom fish, hand-butchering salmon, most crab processing activities, and hand-shucking clams and oysters. Higher levels of treatment are available to these operations if necessary. The only plants which simply grind and discharge their wastes are plants in remote areas of Alaska.

For catfish processing areas, which are usually located inland, simple biological wastewater treatment systems (e.g., aerated lagoons) are applicable. Land for such systems is more available away from coastal areas. In addition, some of the catfish processors have municipal wastewater treatment plants available which can accept processing wastes.

With few exceptions, the waste management concepts and wastewater treatment technologies discussed herein have already been proven by model plants within various segments of the seafood industry. The levels of technology having application to the various industry segments reflect present knowledge concerning their effectiveness and associated costs. They also reflect the special nature of the seafood industry, including its processing operations and geographical location. Moreover, many of the technologies considered applicable to the seafood industry have been applied successfully by related food industries in the United States and abroad. In the United States, related food industries generally utilize the technologies discussed herein along with other more advanced technologies, which are not applicable to the seafood industry, to achieve higher levels of wastewater treatment.

Applicable technologies, associated pollutant reductions and associated costs are presented in Table 1 for the various seafood industry segments.

TABLE 1

WASTE REDUCTIONS AND COSTS RELATED TO APPLICABLE TECHNOLOGY
FOR SPECIFIC SEGMENTS OF THE SEAFOOD INDUSTRY (126)

Technology	In-Place	Industry Application	Waste Reduction	Cost Range	
				Installed	Daily O&M
In-Plant Modification	Tuna	Tuna	Minimize Loadings for Discharge or Subsequent Treatment	$20,000-$220,000	$20 - $250
	Fish Meal (w/solubles)	Fish Meal (w/o solubles)		$270,000-$550,000	$275 - $560
	Catfish Blue Crab West Coast Crab Shrimp Breaded Shrimp Salmon Bottom Fish Clam Oyster Sardine Herring Fillet Abalone	Catfish Blue Crab West Coast Crab Shrimp Breaded Shrimp Salmon Bottom Fish Clam Oyster Sardine Herring Fillet Abalone		Contiguous States $5,000-$75,000 Alaska $10,000-$220,000	 $5 - $75 $5 - $240
Screening	Tuna	Tuna		$48,000-$178,000	$24 - $180
	Catfish Blue Crab West Coast Crab Shrimp Breaded Shrimp Salmon Bottom Fish Clam Oyster Sardine Herring Fillet Abalone	Catfish Blue Crab West Coast Crab Shrimp Breaded Shrimp Salmon Bottom Fish Clam Oyster Sardine Herring Fillet Abalone	Removal of Oversize Solids (Generally larger than 0.03-inch)	Contiguous States $46,000-$160,000 Alaska $79,000-$260,000	 $ 7 - $250 $33 - $270

TABLE 1 (Continued)

Technology	In-Place	Industry Application	Waste Reduction	Cost Range	
				Installed	Daily O&M
Grease Trap	Sardine	Catfish Blue Crab West Coast Crab Sardine	Removal of free oil and grease for recovery	Contiguous States $1,000-$3,000 Alaska $3,000-$11,000	 $2 - $13 $10 - $80
Air Flotation	Tuna	Tuna*	Finfish	$200,000-$800,000	$280-$1,800
		Salmon* Bottom Fish† Sardine* Herring Fillet†	BOD_5: 50-80% TSS: 70-95% O&G: 80-95%		
		Blue Crab† West Coast Crab* Shrimp* Breaded Shrimp† Clam† Oyster*	Shellfish BOD_5: 40-65% TSS: 60-75% O&G: 70-90%	Remaining Segments $178,000-$600,000	 $14-$1,000
Biological Systems Aerated Lagoons	Breaded Shrimp	Catfish Tuna	BOD_5: 75-85% TSS: 70-80% O&G: 85-95%	$110,000-$160,000 $190,000-$2,250,000	$45 - $70 $80-$890
Activated Sludge		Tuna	BOD_5: 80-90% BOD_5: 80-90% TSS: 75-85% O&G: 85-95%	$150,000-$1,000,000	$200-$1,000

*Demonstrated on a full-scale or pilot plant level.
†Engineering judgment based on performance achieved for related industry segments.

III. SEAFOOD WASTE UTILIZATION AND DISPOSAL

Wastes generated by seafood processors, other than the tuna and fish meal segments, are proteinaceous, containing materials which have some value. Seafood processors are not always well-equipped to produce valuable products from their waste materials. It is not always profitable to do so. Simple disposal often represents the cheapest and least cumbersome way to deal with unwanted raw materials from the processing plants. The industry has been utilizing rather convenient, inexpensive disposal options (such as direct ocean discharge of raw wastes) which have tended to discourage additional waste material utilization while potentially affecting receiving water quality. The general philosophy has been that you can put back into the sea substances that came out of the sea.

The more complex the practices for waste material retention or capture, the more need there is for alternatives for the utilization or disposal of these wastes. Tuna canneries have installed lines to produce petfood from portions of the fish which are not acceptable for human consumption. In addition, viscera and scraps are collected for the production of other byproducts, such as meal, oil and solubles, requiring equipment similar to that utilized by the fish meal segment.

Production of fish meal from whole fish (menhaden and anchovies) generates a concentrated waste stream called stickwater. At some facilities, stickwater is combined with unloading water to generate solubles by evaporation. This byproduct can be introduced into the meal drying process or enhance quality or, it can be marketed separately, an approach which has been adopted by some tuna canners.

Tuna processors employing physical-chemical treatment (DAF) for their wastewaters are faced with the disposal of the resulting sludge (float). Currently, disposal is accomplished by conventional means, such as landfilling. Investigations are required to establish the feasibility of producing an animal feed additive, fertilizer from float, or disposal at sea.

For the remaining segments of the industry, enlightened waste material utilization will require improved in-plant waste management to improve solids recovery. Solids which can be collected and potentially utilized include gross solids (heads, viscera, etc.) from the processing lines, screened solids from end-of-pipe treatment systems, the solids captured by physical-chemical wastewater treatment systems (such as DAF), and the solids generated by biological wastewater treatment systems. Once collected, these solids have potential for reuse as foodstuffs, nutrient products, animal feed, fertilizers and other useful materials, depending on the species processed, processing steps employed, chemicals used, and the granting of approval for selected uses by the Food and Drug Administration (FDA). Options for the disposal/utilization of wastes resulting from the implementations of waste management practices are illustrated in Figure 1.

For most finfish species, the production of fish meal offers a means of waste material utilization and disposal. Fish meal plants, similar to those installed at tuna canneries, are operated by independent companies or cooperating seafood processors located in major processing centers. The canning of petfood products has also gained some acceptance as a means of waste material utilization by specific segments of the seafood industry.

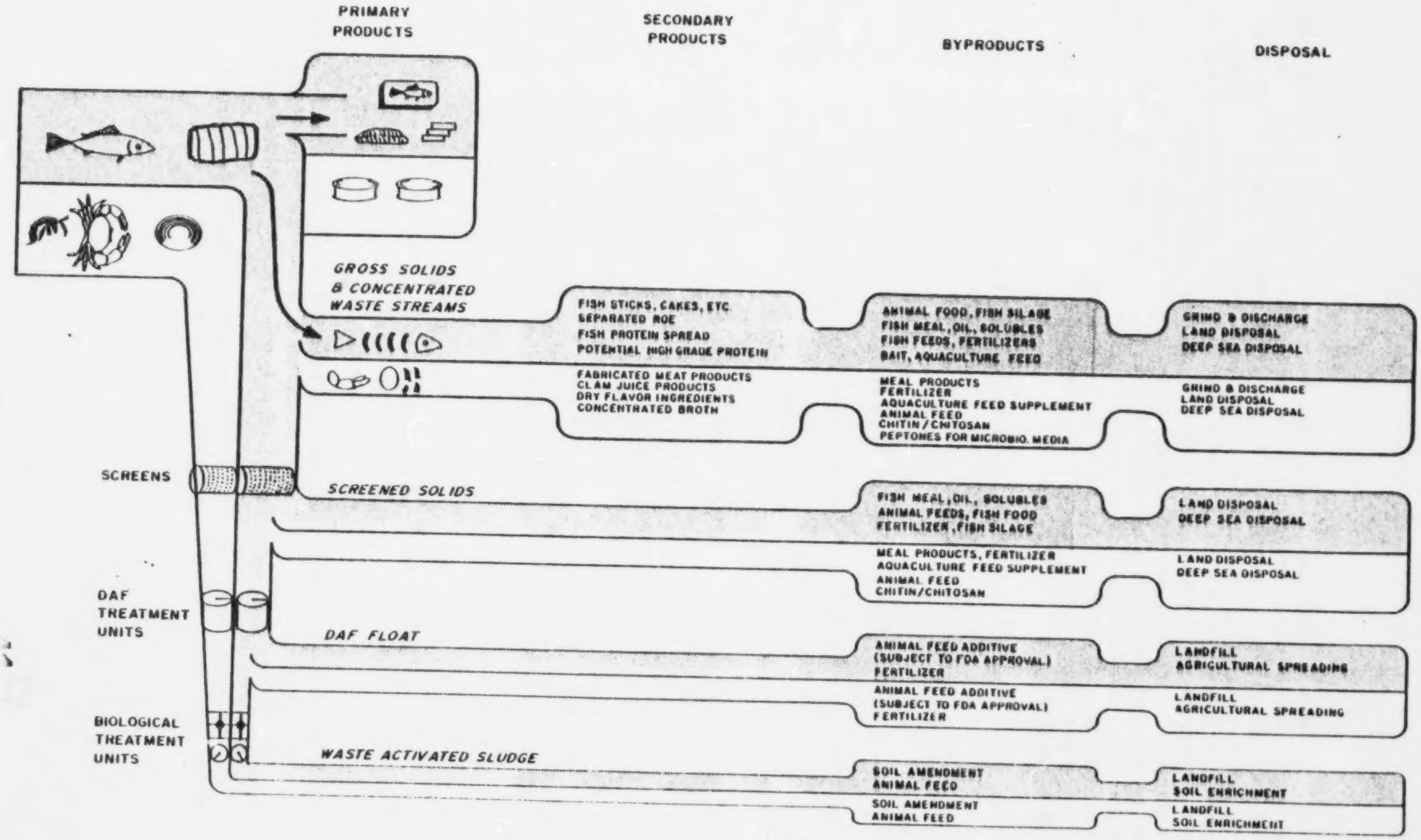
PRIMARY PRODUCTS
SECONDARY PRODUCTS
BYPRODUCTS
DISPOSAL
GROSS SOLIDS & CONCENTRATED WASTE STREAMS
FISH STICKS, CAKES, ETC.
SEPARATED ROE
FISH PROTEIN SPREAD
POTENTIAL HIGH GRADE PROTEIN
ANIMAL FOOD, FISH SILAGE
FISH MEAL, OIL, SOLUBLES
FISH FEEDS, FERTILIZERS
BAIT, AQUACULTURE FEED
GRIND & DISCHARGE
LAND DISPOSAL
DEEP SEA DISPOSAL
FABRICATED MEAT PRODUCTS
CLAM JUICE PRODUCTS
DRY FLAVOR INGREDIENTS
CONCENTRATED BROTH
MEAL PRODUCTS
FERTILIZER
AQUACULTURE FEED SUPPLEMENT
ANIMAL FEED
CHITIN/CHITOSAN
PEPTONES FOR MICROBIO. MEDIA
GRIND & DISCHARGE
LAND DISPOSAL
DEEP SEA DISPOSAL
SCREENS
SCREENED SOLIDS
FISH MEAL, OIL, SOLUBLES
ANIMAL FEEDS, FISH FOOD
FERTILIZER, FISH SILAGE
LAND DISPOSAL
DEEP SEA DISPOSAL
MEAL PRODUCTS, FERTILIZER
AQUACULTURE FEED SUPPLEMENT
ANIMAL FEED
CHITIN/CHITOSAN
LAND DISPOSAL
DEEP SEA DISPOSAL
DAF TREATMENT UNITS
DAF FLOAT
ANIMAL FEED ADDITIVE
(SUBJECT TO FDA APPROVAL)
FERTILIZER
LANDFILL
AGRICULTURAL SPREADING
ANIMAL FEED ADDITIVE
(SUBJECT TO FDA APPROVAL)
FERTILIZER
LANDFILL
AGRICULTURAL SPREADING
BIOLOGICAL TREATMENT UNITS
WASTE ACTIVATED SLUDGE
SOIL AMENDMENT
ANIMAL FEED
LANDFILL
SOIL ENRICHMENT
SOIL AMENDMENT
ANIMAL FEED
LANDFILL
SOIL ENRICHMENT

Figure 1. Utilization and disposal alternatives for wastes resulting from selected levels of waste control technology.

Shellfish wastes (crab and shrimp) can be converted into a meal product, but one which has a lower protein content and poorer market value than the meal from finfish plants. Another byproduct which can be manufactured from shellfish (crab and shrimp) wastes is chitin and its derivative, chitosan. These natural polymers have potential for a wide range of applications, but have not been economically produced in quantity in the United States. A Japanese manufacturer currently provides most of the world's supply of chitin/chitosan. The future may bring greater attention to the properties of these shellfish derivatives, thus attracting a greater market. To be economically competitive, chitin/ chitosan would have to be produced at a large regional or national plant which would need to receive adequate volumes of shellfish wastes from a large number of processors.

Solids which are not converted into byproducts require disposal either on the land or in the ocean. Land application requires the availability of a suitable site. Techniques are available to incorporate seafood processing wastes into the soil to increase nutrient contents in support of agricultural activities. If simple disposal is the key objective, suitable landfill sites can provide the means when they are available.

Conditions in most of the Alaskan processing areas preclude land application or landfilling of seafood processing wastes. For this isolated segment of the industry, alternatives are thus limited to byproduct manufacturing or ocean disposal.

Byproduct alternatives for the Alaskan seafood processors include the manufacture of fish meal and associated products at selected processing centers. Meal plants are currently operated in Seward, Petersburg and Kodiak. The market feasibility of establishing regional meal plants in other Alaskan locations is currently being evaluated by DPRA. Smaller package-type meal plants may also represent a feasible alternative for certain processors. Other byproduct alternatives include freezing of gross finfish solids for shipment to Seattle petfood manufacturers and the stabilization of shells through deproteinization. The stabilized shell material and protein can then be transported to other locations for byproduct manufacturing or other forms of utilization.

Designated ocean disposal sites are located within 5 miles of most Alaskan seafood processing centers. Barging of wastes to these sites can usually be accomplished at a reasonable cost, thus minimizing the impact on near-shore waters.

Progressing to higher levels of waste management will increase the quantity of residuals requiring utilization or disposal. Byproduct production represents a solution for disposal of gross and screened solids at some locations. For DAF sludge disposal, the tuna processors have employed dewatering and landfilling. However, long-term solutions to the disposal requirements for float and waste activated sludges must continue to be sought.

CHAPTER 3

WASTE CONTROL TECHNOLOGY AND ASSOCIATED COSTS

I. GENERAL

The character of the wastes generated by seafood processors relates to the species being processed, the volume of production, and the processing methods utilized. Generally, mechanized operations consume more water and result in higher waste loads per ton of raw material processed than manual techniques. Of the total volume generated, the major portion of the waste consists of gross solids such as heads, viscera, shells and carcasses. The remainder comprises smaller pieces suspended in the process wastewaters. Other types of waste products result from subsequent processing steps to produce specialty items. For example, some shrimp plants incorporate a breading operation as part of their normal activities; this results in the presence of bread crumbs and batter in the process waste streams.

Water is used by seafood processors for a number of operations including the unloading of boats, the transport of raw materials within the plant, various processing steps, and washing and cleanup operations. Additional uses, such as retorting, do not generally result in the contamination of the water; these noncontact flows can be discharged without treatment. Acceptable in-plant management consists of isolating noncontact flows and implementing measures which can reduce the process water use and help control the amount of wastes that are allowed to escape into the floor drains and collection system of the plant. When process contact water has been allowed to leave the processing area, it is known as wastewater.

Concern for the environmental effects of wastewaters discharged to receiving waters by municipal and industrial point sources, including the seafood processors, has led the United States Congress to provide EPA with the authority to issue guidelines for the cleanup and regulation of these discharges. Federal regulations, referred to as secondary treatment and effluent limitations guidelines, have specified the maximum amount of waste materials or pollutants which can be discharged by municipalities and industrial point sources, including seafood processing plants.

So far, much of the seafood industry has done little in terms of controlling waste discharges in comparison to other food processing industries. Other food processors, such as meat packers, poultry processors, and fruits and vegetable plants, have adopted more sophisticated and costly technologies than those implemented by the seafood industry. Although the characteristics of these industries may differ from those of the seafood industry, the concepts relating to waste control and treatment for all are comparable.

The assessments of waste control and treatment which have been accomplished to date have identified special characteristics of the seafood industry. Typical of most segments of the industry are small processing plants which often operate only intermittently during the year. Many of the smaller plants are family-owned. Manual labor is prevalent and waste management practices are often antiquated. An exception is the tuna industry, which typically operates on a larger scale and operates essentially year round. Most tuna processors also employ more sophisticated waste treatment technologies than other segments of the industry. Modern fish meal facilities also represent a higher level of sophistication in terms of waste management.

For the most part, seafood processors are located in built-up shorefront areas. Some are actually built over the water on piles, and still others are located on seagoing vessels. In many instances, processors have limited land available for expansion or the construction of wastewater treatment facilities.

Technologies for reducing the discharge of solid and liquid wastes from seafood processing plants can be segregated into two categories. The first category encompasses in-plant management techniques and modified operating procedures. The second classification involves equipment and appurtenances which treat the wastewater after it has left the processing areas. These are referred to as "end-of-pipe" technologies and generally represent a more elaborate approach to waste control than in-plant modifications.

II. IN-PLANT MANAGEMENT

In-plant management techniques and modified operating procedures constitute two major areas: 1) water management (i.e., the reduction of water consumption through housekeeping methods and/or recycle/reuse); and 2) waste management (i.e., control of waste materials allowed to enter the plant effluent). Both water conservation and waste management can help reduce the cost of implementing end-of-pipe treatment technologies. Decreased water usage can reduce the total volume of wastewater which requires treatment, thus minimizing the required size of treatment equipment and the associated capital and operating costs. When the flow to treatment is reduced, the greater cost savings are realized in total capital investment, with a lesser impact on use-associated costs. Similarly, by decreasing the amount of solids which enter the waste stream, one reduces the amount of wastes which must be removed by end-of-pipe treatment technologies. Again, equipment sizes and use-associated treatment costs, which includes the handling and disposal of residuals, can then be reduced.

Table 2 illustrates the impact of in-plant measures on the costs of installing and operating end-of-pipe treatment facilities. Representative seafood industry segments are listed in the table, and treatment costs are compared based on water use for a "model" plant and for a plant which lacks sufficient in-plant controls. The model plants and other plants, although not named, represent existing plants which were characterized during the study to reassess the effluent guidelines for the seafood industry.(126) Model plants are those which are achieving baseline water use and waste load values established for the particular segment.

The model plants generate less wastewater than plants which lack in-plant management practices, reflecting the use of water-saving techniques by most model plants. Since operating costs are more directly impacted by flow, the cost savings are more apparent for daily operation and maintenance (O&M) for all selected segments. Cost comparisons show that processing plants in certain segments can achieve pollution control at a lower capital investment by implementing in-plant modifications prior to installing wastewater treatment

TABLE 2

COST SAVINGS RESULTING FROM THE IMPLEMENTATION OF IN-PLANT MEASURES TO REDUCE WATER USE AND WASTE LOADS

Industry Segment	Plant Size (Tons/Day)	Type Of Plant	Total Daily Flow (MGD)	In-Plant Cost		End-Of-Pipe Cost		Cost Savings	
				Capital ($1,000)	O&M ($/Day)	Capital ($1,000)	O&M ($/Day)	Capital ($1,000)	O&M ($/Day)
Northern Shrimp	8	Model	0.10	15	10	295	415	--	55
		Other	0.14	0	0	300	480		
Tuna	250	Model	0.67	120	130	470	760	80	280
		Other	1.14	0	0	670	1,170		
Mechanized Salmon	35	Model	0.12	45	40	275	315	--	185
		Other	0.17	0	0	310	500		
Mechanized Bottom Fish	30	Model	0.09	35	25	310	380	--	55
		Other	0.12	0	0	340	460		
Steamed and Canned Oyster	7	Model	0.12	10	5	290	465	20	70
		Other	0.14	0	0	320	540		

facilities. Higher initial costs can be often justified in terms of operating cost savings.

Comprehensive water and waste management programs have been shown to produce economic benefits for seafood processors which can break away from traditional practices of discharging wastes directly to receiving waters with little regard to either volume or composition. In-plant modifications and techniques associated with comprehensive water and waste management programs are described below.

A. Water Management

Reduced water consumption is the principle goal of water management. Another objective is to minimize contact between solids and water, since this allows organics and proteins to dissolve in the water. Simple methods can be used to reduce consumption and minimize solids-water contact.

Many processors use water to unload and transport raw and/or finished products within the plant. In some facilities, hydraulic conveyance of waste materials is also typical. Such practices could be modified by installing conveyor belts or pneumatic (vacuum) conveying systems. Pneumatic equipment has been used by plants within various segments of the industry to unload raw material from boats and to convey waste materials from separation equpment to storage. Spring-loaded hose nozzles which automatically shutoff when not in use are commercially available to help conserve water. Faucets can be installed at individual stations along manual butchering tables so that water at an unoccupied station can be turned off. The installation of high-pressure hose and faucet nozzles and the use of high pressure/low-volume water supply systems are other ways to reduce water consumption within a processing facility.

Some processing steps produce more wastes than others. Extremely contaminated water from these areas can be isolated from the main waste stream and subjected to separate recovery operations or treatment processes.

More sophisticated water management methods involve the recycle and reuse of water. Some canneries recycle water which is used to unload boats. Less contaminated waste streams can often be directed to receiving areas or raw material washing operations for reuse without treatment. Water which is used to thaw frozen fish could be reheated and recycled as shown in Figure 2. A similar approach can be used for washing sealed cans.

In some cases, isolated waste streams can be converted into useful products. For example, an east coast clam processor converts water used to wash minced clam meats into a marketable product comparable to clam juice.(66, 161) Investigations have demonstrated the potential of further processing this concentrated material into a dry clam flavor ingredient.(74)

In-plant measures such as those mentioned above normally require that production managers and employees of a given processing plant become more aware of conservation techniques and their impact on total plant water use. Most efforts (such as turning off faucets, hoses, and processing equipment which require water for operation) are simple, direct and inexpensive ways to reduce overall pollution abatement costs for a particular plant.

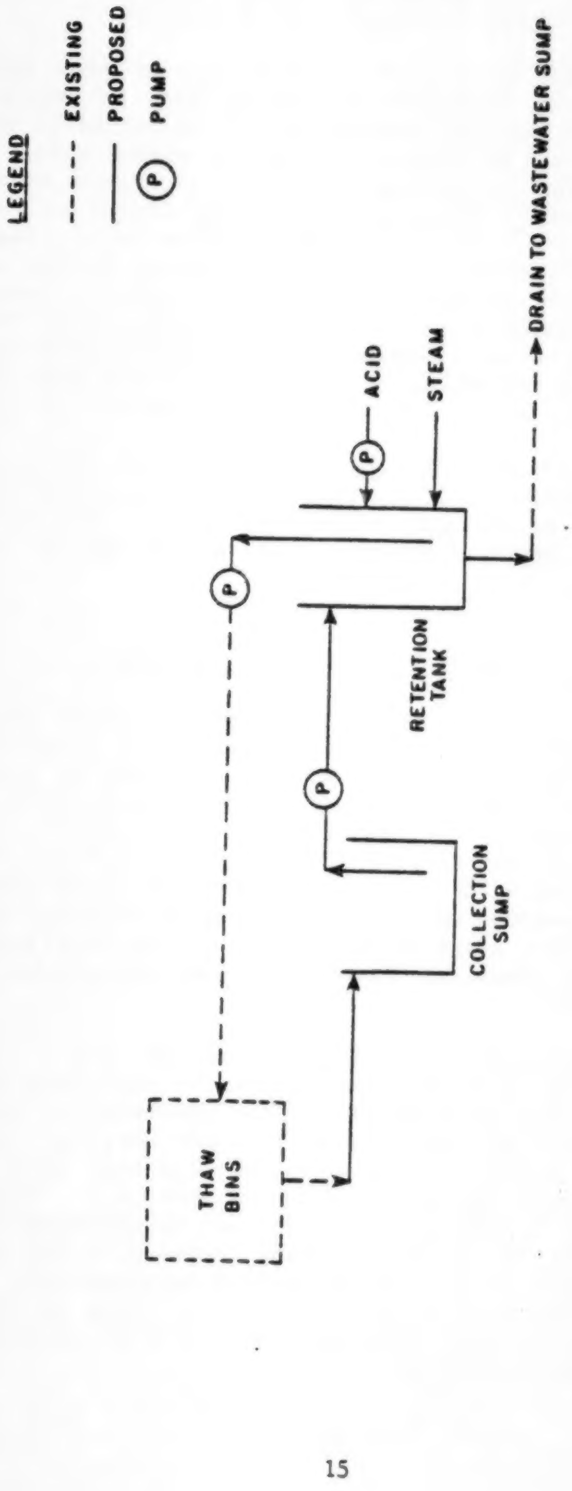
LEGEND
EXISTING
PROPOSED
P PUMP
ACID
P
STEAM
DRAIN TO WASTEWATER SUMP
P
RETENTION TANK
P
COLLECTION SUMP
THAW BINS

Figure 2. Schematic diagram of thaw water recycle system.

B. Waste Management and Associated Byproducts

The principal goal of waste management is to collect the relatively large pieces of waste, such as fish carcasses, viscera, shells, discarded scraps, etc., before they enter the waste streams. A major advantage of this concept is that it provides greater potential for utilizing or converting waste materials into marketable secondary products or byproducts.

Simple waste management techniques are available to most seafood processors. Brooms, shovels, and/or squeegees can be employed as important tools during dry cleanup efforts to collect scraps which have fallen to the floor. Solids which are collected in this manner will not be washed into a drain or require removal by end-of-pipe technology. Another technique consists of placing containers under conveyor belts and processing tables to collect falling or discarded scraps. Once collected, certain waste solids can be utilized to manufacture either secondary products or byproducts having some value. Some progress has been made in this area; however, efforts toward achieving the concept of total utilization have, for the most part, been more fully explored by researchers. Individual byproducts and secondary products currently being manufactured or having potential for future production from finfish and shellfish wastes are identified in Tables 3 and 4, respectively.

The secondary products and byproducts which can be manufactured from waste solids will be discussed in more detail in the next chapter of this report, entitled "Seafood Waste Utilization and Disposal". That discussion will also address disposal alternatives for plants which lack the opportunity to utilize their waste materials.

C. Current Application of In-Plant Control Measures

In-plant control measures to effectively manage waste have been generally lacking in the seafood industry. The reluctance of processors to adopt comprehensive waste management programs can be attributed to two factors: 1) the maintenance of traditional practices and conceptions which are based on the rationale of "returning to the sea what came from the sea;" and 2) the relatively unsophisticated end-of-pipe technology adopted by the industry which does not emphasize the need for reducing incoming waste loads. For example, plants located in remote areas of Alaska grind processing wastes for discharge. In non-remote areas of Alaska and in the contiguous United States, general housekeeping practices for controlling wastewater generation at its source are encouraged.

With the proper incentives, all segments of the industry can identify and adopt the appropriate, in-plant water and waste management practices. Allowing plants to continue grinding wastes for discharge to the marine environment, as is currently performed, does not provide the required incentives. The elimination of flumes for raw material, finished product and waste conveyance and replacement by dry handling methods is an example of a simpler, but effective means of reducing water use and solids-water contact. With the application of higher levels of treatment technology, the primary step is to evaluate in-plant activities. It is readily apparent that in-plant measures and process modification will play an important role in minimizing the economic impact on the industry when implementing more sophisticated and costly end-of-pipe treatment technology.

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TABLE 3

UTILIZATION OF FINFISH WASTES

Commodities Currently Being Produced and Marketed:

a. Fish meal
b. Fish oil
c. Fish solubles
d. Fish silage
e. Petfood
f. Machine separated flesh for use in:

    1. dips
    2. snacks
    3. frankfurters
    4. fish cakes
    5. fish sticks
    6. fish loaves

g. Fertilizer
h. Fish feeds
i. Bait

Byproducts which have been Investigated or Suggested:

a. Feeds for use in aquaculture (i.e. the artificial cultivation of aquatic animals)
b. Recovered protein
c. Single-cell protein production (e.g. using fish wastes to grow yeast cultures)
d. Compost nutrients
e. Anti-coagulant drugs

TABLE 4

UTILIZATION OF SHELLFISH WASTES

Commodities Currently Being Produced and Marketed:

a. Crab Meal
b. Fertilizer (37)
c. Construction products, e.g. oyster shells (32)
d. Clutch-planting media for maintaining the productivity of oyster beds, e.g. oyster shells (32)
e. Hog feed, e.g. clam shells and crab shells (32)
f. Scouring agent for vegetable processing (95)

Byproducts Which Have Been Investigated or Suggested:

a. Chitin (from crab or shrimp shells)
b. Chitosan (from crab or shrimp shells)
c. Industrial acid neutralizer, e.g. clam and oyster shells (95)
d. Substitute in pressed wood panels (95)
e. Texture material for paints (95)
f. Abrasives (95)
g. Filter for oil well drilling mud (95)
h. Component in winter tires (95)
i. Pigmentation ingredient (98)

III. END-OF-PIPE TREATMENT

Even the best water and waste management techniques cannot completely eliminate wastewater from a processing plant. Many technologies are available for treating this wastewater, ranging from relatively simple separation techniques to advanced biological and physical-chemical processes. More advanced technologies generally produce cleaner discharges, but at higher costs. Moreover, the removal of more pollutants results in a greater volume of residuals requiring disposal.

The levels of treatment employed by seafood processors have generally been low, reflecting the nature of the industry. In certain areas of Alaska, in-place technology consists of grinding the wastes then discharging the solids through an outfall which is either submerged or above the water line. The grinding approach which was conceived to facilitate solids dispersal is consistent with EPA policy for designated Alaskan areas. However, this approach cannot be readily considered a total solution for handling the overall waste disposal problem.(26)

In a few areas where processors are discharging to receiving waters (usually inland waters) with water quality considerations, more complex treatment is currently required by state-level environmental control agencies. However, the technology is available for seafood processors, in general, to further reduce wastes which are discharged to the marine environment. End-of-pipe treatment approaches being utilized or currently available to the industry are described below.

A. Screening

In general, screening is the primary step in removing solids from wastewaters generated by the food industry. Meat packers and poultry processors employ screening equipment prior to subjecting process waters to higher levels of treatment. However, most seafood processors use screens to capture solids from the wastewater prior to discharging to receiving waters. Screened solids are usually collected in hoppers, totes, trucks, etc., and in some cases are used to manufacture byproducts. Available screening devices for gross and fine solids removal include the following.

Coarse solids removal equipment:

a. revolving drums (inclined and horizontal);

b. basket screens;

c. belt screens;

d. inclined troughs;

e. bar screens; and

f. drilled plates.

Fine screening equipment (20-mesh equivalent):

a. revolving drums (inclined, horizontal, and vertical axes);

b. tangential screens (pressure or gravity fed); and

c. vibrating or oscillating screens (linear or circular motion).

As indicated above, a variety of solids recovery equipment with various sizes of openings is available to the processor. Frequently, a coarse screen is used ahead of and in series with fine screens. The most common equipment for gross solids removal has been observed to be the revolving drum-type. Screen opening sizes are generally ¼-inch diameter or larger. These units remove the larger solids and reduce loadings to fine screens. Revolving drums and tangential screens are commonly used by the seafood industry for fine screening and are illustrated in Figures 3 and 4, respectively. Current practices include the use of fine screens by most segments of the industry. Figure 5 is a schematic diagram of a typical screening installation which includes a collection sump, pump(s), screen(s), solids conveyance and solids storage hopper. An outfall is also required to direct the screened effluent to marine waters or subsequent treatment.

B. Oil Separation

Many marine animals contain natural fats (oil and grease) which can find their way into the process wastewater. Particularly oily species, such as sardines, may contribute so much fat that special techniques for its removal may be justified. Grease traps and oil skimming mechanisms are used for this purpose. In many instances, the recovered material can be reprocessed into a salable byproduct.

1. Grease Traps. Earlier investigations indicated grease traps to be applicable technology for selected segments of the industry, including catfish and crab processors. Grease traps are basically tanks which allow the fats, which are lighter than water, to rise to the surface where they can be removed either by manual or by mechanical means. Figure 6 illustrates typical configurations for a grease trap which can reduce the quantity of fats and oils entering receiving waters where they would float to the surface.

2. Oil Skimming. Oil skimming, which functions under the same principles as grease traps, has been adopted by the sardine canning industry for a small concentrated waste stream. The wastewater resulting from the precooking operation is isolated and directed to the skimmer, where free oil is recovered for sale to a renderer. Therefore, a portion of the costs associated with this equipment is recovered through the sale of a waste material.

C. Sedimentation

Pollutant particles which are heavier than water will tend to settle to the bottom of a quiescent tank. The level of technology which takes advantage of

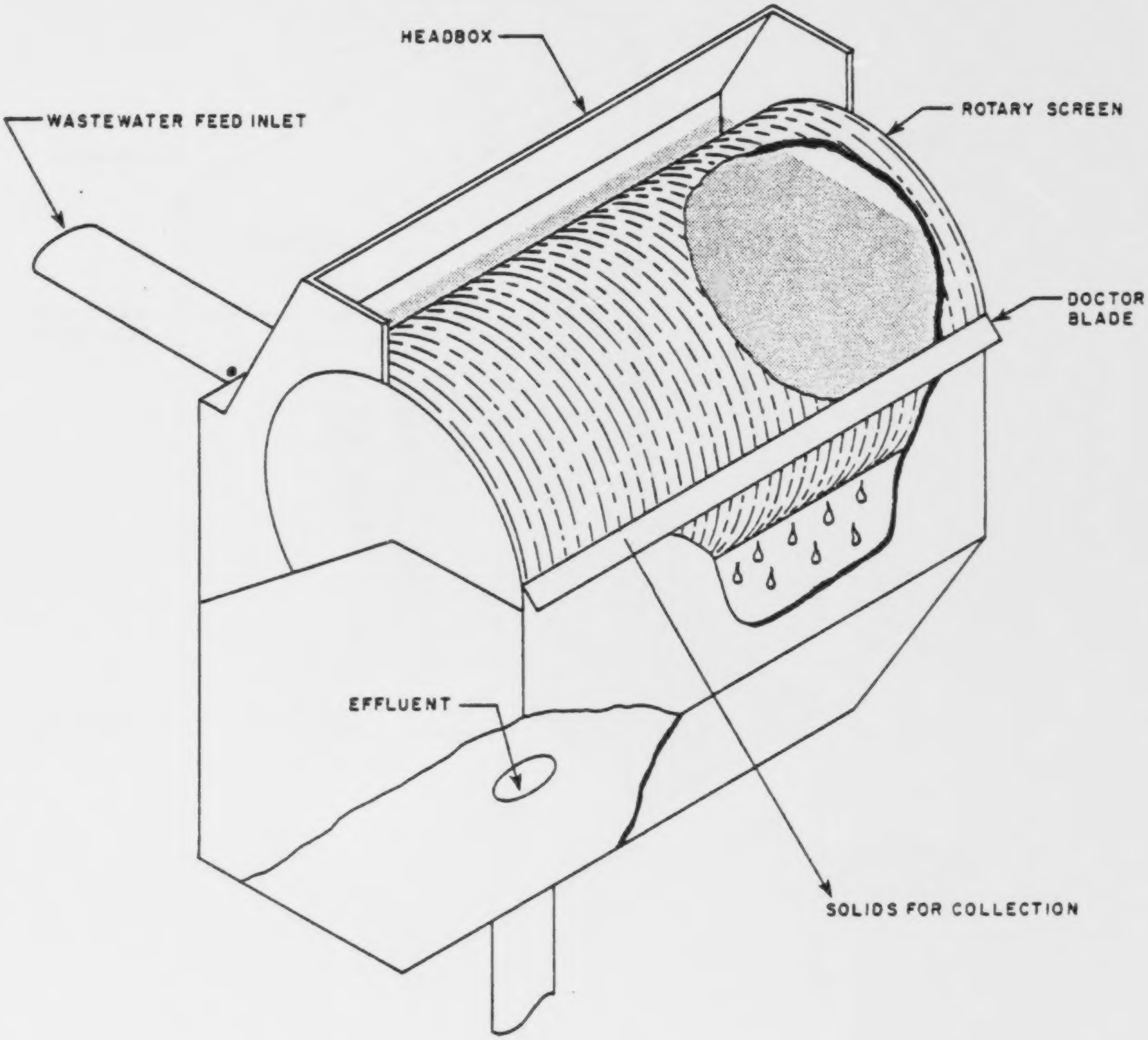
HEADBOX
WASTEWATER FEED INLET
ROTARY SCREEN
DOCTOR BLADE
EFFLUENT
SOLIDS FOR COLLECTION

Figure 3. Perspective view of a horizontal rotary screen or Rotostrainer (Hycor Corporation).

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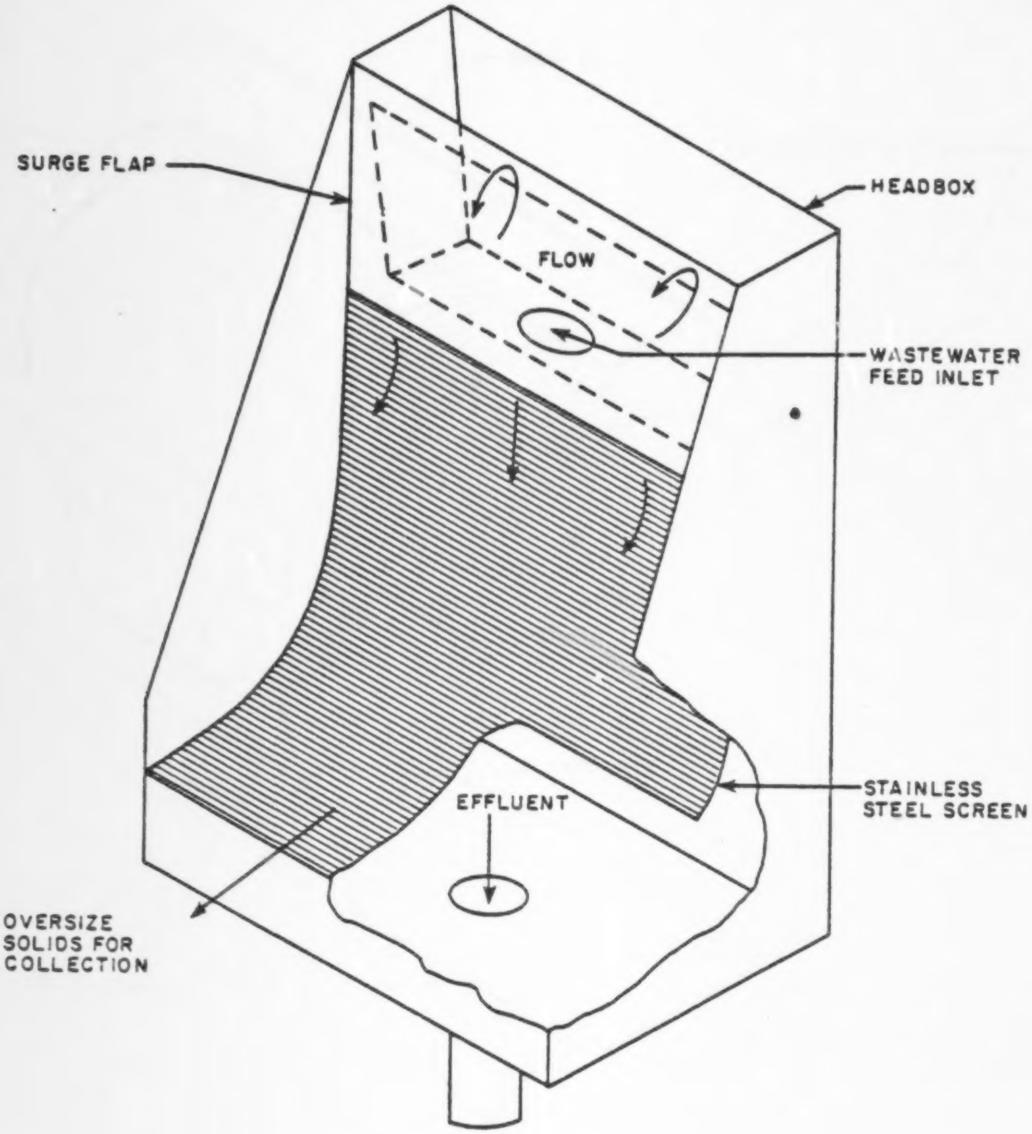

SURGE FLAP
HEADBOX
FLOW
WASTEWATER FEED INLET
STAINLESS STEEL SCREEN
EFFLUENT
OVERSIZE SOLIDS FOR COLLECTION

Figure 4. Perspective view of a tangential or static screen.

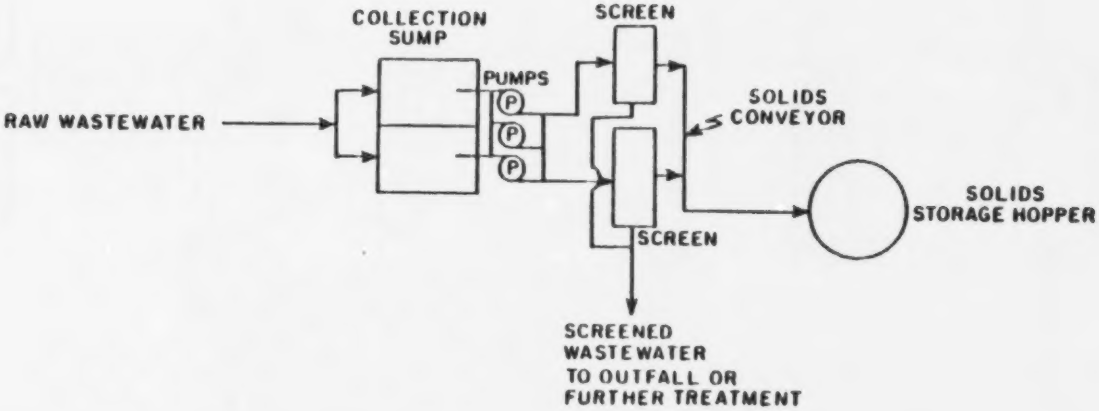
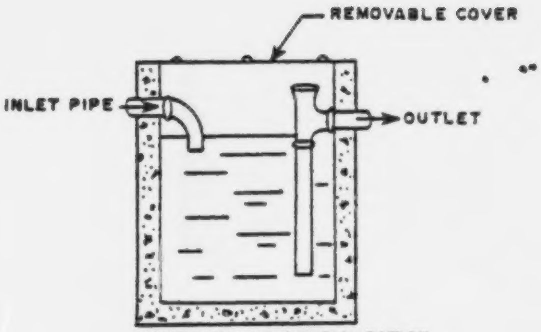
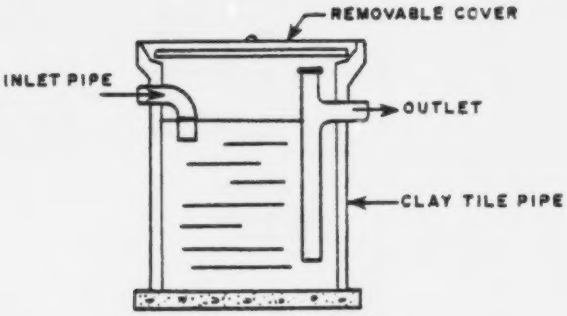

COLLECTION SUMP
SCREEN
PUMPS
P
P
P
RAW WASTEWATER
SOLIDS CONVEYOR
SOLIDS STORAGE HOPPER
SCREEN
SCREENED WASTEWATER TO OUTFALL OR FURTHER TREATMENT

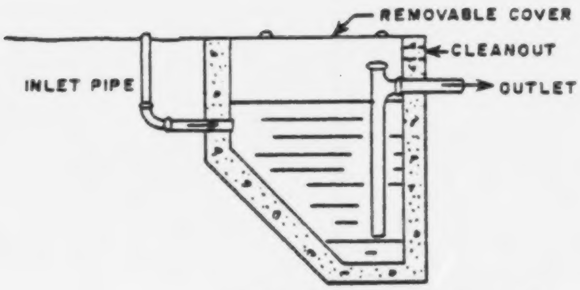
Figure 5. Schematic layout for a wastewater screening system.


REMOVABLE COVER
INLET PIPE
OUTLET

RECTANGULAR CONFIGURATION
USING A CONCRETE BOX


REMOVABLE COVER
INLET PIPE
OUTLET
CLAY TILE PIPE

CIRCULAR CONFIGURATION
USING CLAY TILE PIPE


REMOVABLE COVER
CLEANOUT
INLET PIPE
OUTLET

CONVENTIONAL CONFIGURATION
FOR SMALLER VOLUMES

Figure 6. Typical grease trap configurations.

this principle is called sedimentation, and includes grit chambers, sedimentation tanks and clarifiers.

Grit chambers have been found to be applicable to clam and oyster processors. They are designed to remove heavy, "gritty" materials such as sand, dirt, and shell fragments which could erode or damage wastewater treatment equipment. When installed, grit chambers are commonly placed before screens or any other treatment equipment.

Sedimentation is not applicable for the majority of the seafood industry. To accomplish separation of organic solids, wastewater needs to be retained in the tanks for long periods of time. The putrescible nature of fish wastes prohibits the use of sedimentation by most of the industry.

D. Biological Treatment

Biological treatment systems are designed to foster the growth of microorganisms which are capable of decomposing waste matter. Most systems require the removal of larger solids and consist of a mixed culture of microorganisms which include protozoans, bacteria, yeast and rotifers. Keeping these organisms propogating presents a difficulty for seafood processors which do not maintain a regular schedule or process year-round. When their activities cease, no wastes are generated and the organisms are thus deprived of their food source. Although short-term interruptions may not significantly impair the effectiveness of certain systems, extended shutdown periods would require that the organisms be provided with a supplemental energy source, such as fish food, to maintain acceptable pollutant removals. Other considerations include sudden increases in waste loads, called shock loadings, which can have an adverse effect on the organisms involved. In addition, cold temperatures slow down the activity of the organisms, thus decreasing the efficiency of biological systems.

Although they have not received widespread application within the seafood industry, biological processes comprise a common technology for the treatment of municipal wastewaters and other effluents generated by some segments of the food processing industry. The organisms effecting treatment within the system can be maintained in liquid suspension, or they can attach themselves to fixed surfaces. Fixed-growth systems, which include trickling filters and rotating biological contactors (RBC), offer a greater resistance to shock loads than the suspended biomass systems, particularly if multiple stages of treatment are used. However, the attached biomass requires exposure to air as an oxygen source. To prevent freezing during winter operation in northern climates, trickling filters and RBC's can be covered or installed in a building.

Biological systems can be generally classified according to the type of environment provided for the life forms. Aerobic systems promote the growth of organisms which can exist in the presence of dissolved oxygen, whereas anaerobic systems are limited to organisms that thrive in the absence of oxygen. Various biological processes have been adopted by industries and municipalities to reduce organic loads discharged to receiving waters. Lagoon treatment which employs either an aerobic or anaerobic process represents a low-activity system. Examples of high-rate aerobic systems include the fixed growth processes and activated sludge systems.

Wastewater which leaves a high-rate biological reactor carries clumps, or flocs, of microorganisms and solids with it. Sedimentation techniques, as discussed earlier, are then required to remove the flocculated organisms and related solids. A clarifier, which can be a circular tank ranging from 50 ft to 300 ft in diameter, follows the biological reactor for this purpose. Although areas required for the high-rate biological systems themselves can be relatively small, additional land is necessary to accommodate the clarifiers and any other ancillary equipment.

Several alternatives exist for both high-rate biological systems and lagoon treatment, each with inherent advantages and disadvantages. A brief discussion of the available options for achieving secondary treatment of wastewaters is provided below.

1. Activated Sludge Processes. Activated sludge treatment and its modifications are aerobic, suspended growth processes. Wastewater is conveyed to an aeration tank, into which air (oxygen) is mechanically introduced to sustain biological activity. When properly designed and skillfully operated, such systems can achieve high degrees of treatment, particularly for BOD_5. Conventional systems retain the wastewater for 24 hours or less. A modification of the activated sludge process is extended aeration, in which the wastewater is retained in the aeration tank for longer periods of time. Extended aeration systems can better tolerate shock loadings which are characteristic of many food processing operations. Application of the extended aeration process has been demonstrated on pilot plant and full-scale levels.(39, 86) All activated sludge systems generate biomass which must be wasted and then handled for ultimate disposal.

2. Trickling Filters. Trickling filters are basically large circular tanks filled with plastic media or rocks. Wastewater is distributed over the surface of the filter with spray nozzles. As wastewater filters down through the media, it is brought into contact with microorganisms attached to the media. The mass of the microorganisms increases with continued wastewater application, and eventually sloughing will occur. Thus, the treated wastewater and clumps of biomass are directed from the bottom of the filter to a sedimentation tank which allows phase separation to occur for discharge of clarified effluent. The resulting sludge (biomass) is generally dewatered further for ultimate disposal.

In recent years, the trickling filter approach has decreased in relative importance as a means for achieving secondary treatment. However, its application to reduce organic loadings prior to activated sludge processes has gained acceptance.

3. Rotating Biological Contactors (RBC). Another example of the fixed biomass approach is rotating biological contactors. As shown in Figure 7, RBC systems contain a series of disks arranged along a horizontal axis and represents a compact system. The disks are partially submerged in the wastewater. As these disks rotate, microorganisms which attach themselves to the disks are alternately submerged and removed from the liquid. Aerobic oxidation is effected, thus increasing the biomass on the media. As the biomass

grows and rotates, the sloughing phenomenon occurs. Clarification must follow the contactors to obtain an acceptable effluent for discharge. The separated biological solids are handled in much the same manner as those removed from trickling filter effluents. The effectiveness of the RBC process for seafood processing wastewaters has been investigated for fish and shellfish operations on a small scale.(3, 70)

4. Lagoon Treatment. Wastewater treatment lagoons are usually flat-bottomed basins enclosed by sloped, earthen dikes. The depth of the basins varies with the specific type of process selected. For example, aerobic ponds assume a liquid depth of 2 to 5 ft while anaerobic lagoons may be up to 20 ft deep. Because they contain such large volumes of wastewater, lagoons are not highly sensitive to fluctuations in hydraulic and organic loadings. As a result, the systems can offer reasonable long-term performance in treating the intermittent waste loads generally associated with the seafood industry.

Other food processing industries use various modes of wastewater lagooning, including aerobic and anaerobic processes. The oxygen required to maintain aerobic conditions can be introduced into the basins either naturally or mechanically. If air is mechanically forced into the wastewater, the lagoons can be deeper, which is an advantage in cold climates and areas with limited land availability.

Aeration is not required in anaerobic lagoons. However, the organisms which are used in an anaerobic system are less active than those available in aerobic systems. Consequently, the wastewater must be retained in the lagoon for a longer period of time. Longer retention periods require larger land areas. In addition, the salt content of some seafood processing wastewaters can have a harmful impact on the anaerobic organisms.(115) Odors associated with anaerobic treatment can also pose a problem.

Indications are that more interest has been generated regarding lagoon treatment of seafood wastewaters than for other biological alternatives previously mentioned. Aerobic lagoons have been investigated for treating shrimp, crab, and clam processing wastewaters.(68, 136, 162) Conventional anaerobic processes have been studied for crab and shrimp process waters; however, they were not found to be well suited to screened breaded shrimp wastewaters. (113, 135) The major disadvantage of both types of lagoons is their relatively large land requirement.

5. Biological Treatment With Macroorganisms. Life forms larger than microorganisms can also be used to remove pollutants from wastewaters, and then harvested for non-human consumptive uses. One investigator has studied the use of municipal wastewaters as a food source for crustaceans and finfish.(157) Similar schemes have reduced pollutant levels in the wastewater, while producing harvestable and marketable products. Fish grown in wastewater can be used for bait, restocking, petfood or other non-human consumptive uses. Other investigators have used municipal wastewater to grow algae, which was then fed to bivalve mollusks, lobsters and finfish.(41, 56, 91, 131, 132)

Additional studies have shown that fish processing wastes can serve as food sources for crab and salmon. Moreover, seafood wastes were found to be competitive with commercially available fish foods.(133, 157)

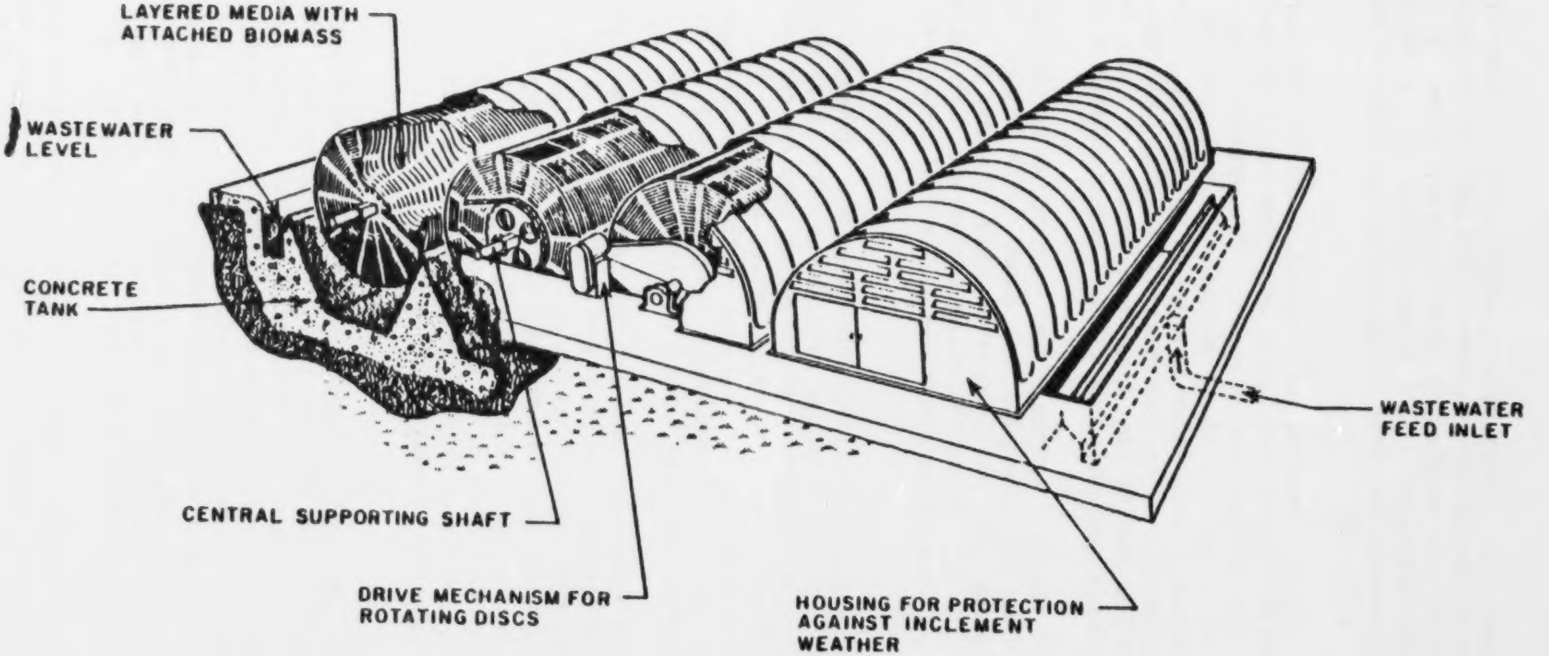

LAYERED MEDIA WITH ATTACHED BIOMASS
WASTEWATER LEVEL
CONCRETE TANK
CENTRAL SUPPORTING SHAFT
DRIVE MECHANISM FOR ROTATING DISCS
HOUSING FOR PROTECTION AGAINST INCLEMENT WEATHER
WASTEWATER FEED INLET

Figure 7. Perspective view of rotating biological contactors or Bio-Surf process (Autotrol Corporation).

6. Summary - Biological Treatment. In general, activated sludge treatment systems would have some difficulty in effectively treating the wastewaters emanating from seafood processing plants which operate intermittently. Extended aeration represents the most attractive modification for effluents of this nature. Attached growth systems, such as trickling filters and RBC's, would be inhibited similarly, but to a lesser degree. Clarification is required for all of these high-rate aerobic processes. Such systems are more applicable to continuously-operated plants, such as the larger tuna canneries, which have a consistent supply of raw material. Vessels travel thousands of miles year-round to harvest fish and return them to port. This practice enables most tuna canneries to process year-round at a normalized rate of production. Nevertheless, the limiting factor for this processing segment is the availability of sufficient land to expand existing treatment facilities. Although high-rate systems require smaller reactors, additional area must be provided for clarification.

Aerated lagoons can reliably handle the intermittent and highly variable waste loads which are characteristic of the major portion of the seafood industry. Studies have shown that finfish and shellfish wastewaters can be adequately treated in aerated lagoons. The major disadvantage of lagoons is their land requirement, which limits their application to most subcategories. Limitations on land availability are apparently not a problem for catfish processors which are located inland, away from coastal zones.

E. Physical-Chemical Treatment

Physical-chemical treatment technology employs nonbiological processes to remove pollutants from wastewater. Processes of this nature are usually applied after more basic treatment, such as screening, has already removed larger solids from the waste stream. Solids which remain are mostly small and evenly dispersed throughout the liquid. Certain physical-chemical processes promote the gathering and isolation of these smaller particles so they can be removed from the wastewater more easily. For example, chemicals can be added to help precipitate certain pollutants from solution. Electrical charge fields can also help stabilize charged particles to facilitate coagulation and eventually their removal from solution.

1. Flotation. One of the most common forms of physical-chemical treatment for food processing wastewaters is flotation, in which chemicals and gas bubbles are introduced into the wastewater. In a tank, the chemicals help fine solids and oil particles gather into clumps or flocs. Tiny gas bubbles attach themselves to these flocs, assisting them to the surface of the water. The floating material is then mechanically skimmed away, leaving an intermediate layer of clearer water behind. Heavier solids settle to the bottom of the tank and are removed periodically.

Because flotation represents a relatively simple technology and takes up less space than sedimentation, it has received considerable attention with regard to treating wastewaters generated by the seafood industry. It is also better suited to the types of wastewaters generated by much of the industry. Red meat, poultry processing and rendering industries have made extensive use of flotation, usually preceding biological treatment facilities.

The application of flotation technology to a variety of related seafood processing effluents has been discussed by a number of foreign sources. Specifically, successful treatment of wastewaters has been achieved for Japanese facilities which process cod, mackerel, squid, tuna and sardines.(248, 249) Flotation has also been described for fish oil and protein recovery.(76) Government reports for seven Swedish processing plants addressed the physical-chemical treatment of food processing effluents, including fish wastewaters and combined waste streams.(202, 205, 206, 234, 248, 249, 250)

Flotation methods, which are classified according to the technique used to produce the tiny gas bubbles, include: a) vacuum flotation; b) dissolved air flotation (DAF); c) dispersed air flotation; and d) electroflotation. These methods are described below.

a. Vacuum Flotation

Vacuum flotation has not received widespread acceptance within the food processing industry or for other conventional applications.

b. Dissolved Air Flotation

As shown in Figure 8, dissolved air flotation (DAF) relies on a pressurized tank, where air is dissolved into the wastewater at conditions above atmospheric pressure. This pressure is relieved in the flotation tank, allowing tiny air bubbles to form and rise to the surface. This effervescence is analagous to the bubbling of a carbonated soft drink after it is opened. As the air bubbles rise, they carry with them many of the pollutant particles, oil and grease suspended in the wastewater.

As early as 1970, the application of DAF technology to the seafood industry was investigated. Specific wastewaters examined included those generated by the processing of salmon, bottomfish, and sardine.(5, 35) Less elaborate studies have addressed the flotation of herring crab and shrimp processing effluents.

DAF technology is currently being used at a number of tuna canneries in California, Puerto Rico and American Samoa.(46, 48) It has also been investigated on a full-scale level for a shrimp and oyster cannery in Louisiana.(83)

Screening is employed prior to flotation at all in-place facilities. A variety of substances are commercially available for chemically treating the wastewater prior to flotation. Although chemical conditioning limits the disposal/utilization options for the floated material, the available information indicates that chemical conditioning is necessary to provide acceptable performance for dissolved air flotation systems. Only one facility, a California tuna cannery, has elected not to add chemicals to enhance pollutant removals from process wastewaters. However, additional equipment which is capable of reducing pollutant loadings to the DAF system has been provided.

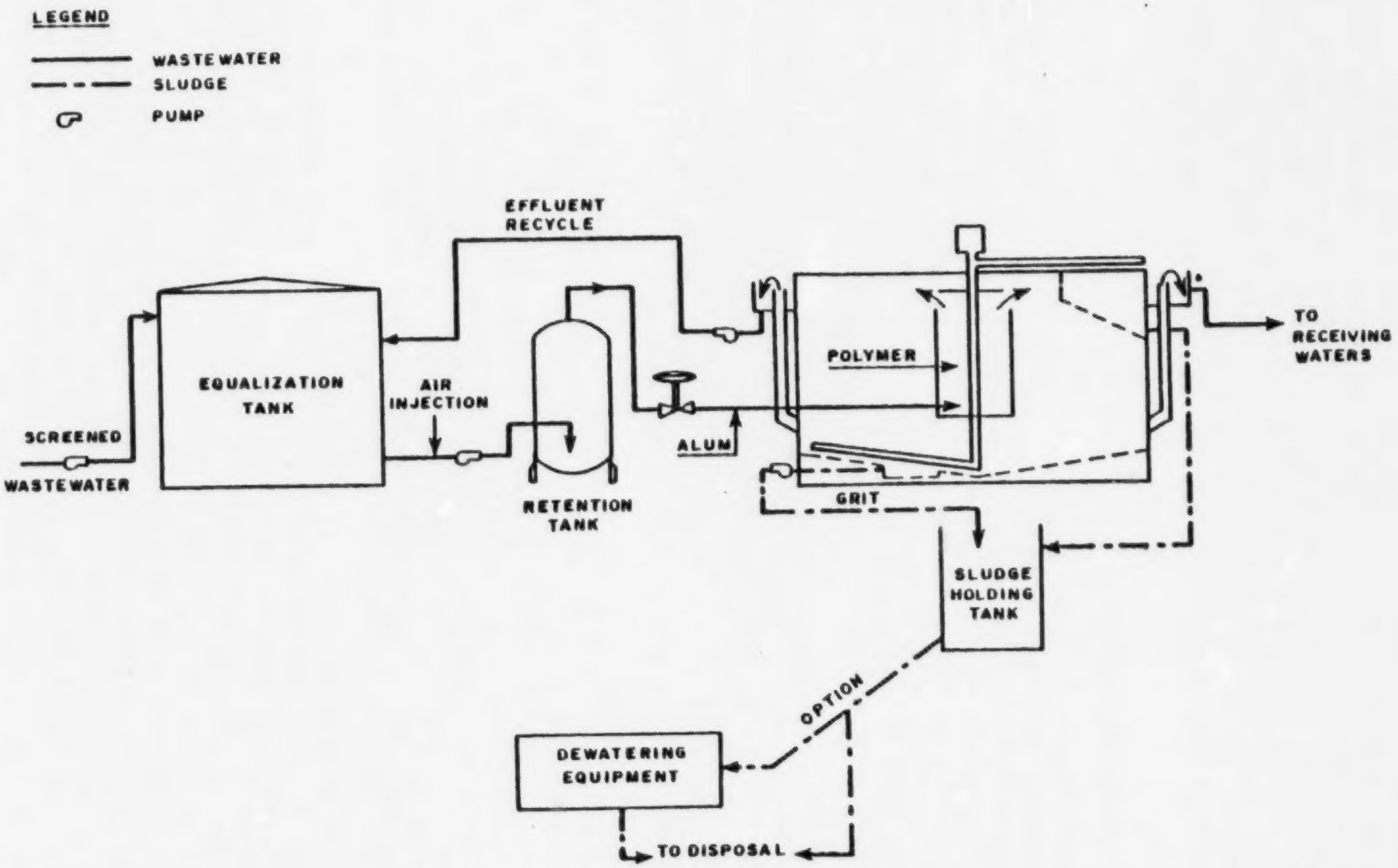

LEGEND
WASTEWATER
SLUDGE
PUMP
EFFLUENT RECYCLE
EQUALIZATION TANK
AIR INJECTION
SCREENED WASTEWATER
RETENTION TANK
ALUM
POLYMER
GRIT
TO RECEIVING WATERS
SLUDGE HOLDING TANK
OPTION
DEWATERING EQUIPMENT
TO DISPOSAL

Figure 8. Schematic diagram of dissolved air flotation (DAF) treatment system.

C3

c. Dispersed Air Flotation

Disperse air flotation technology introduces air bubbles into the wastewater mechanically or by direct injection at the bottom of a flotation tank. This approach has been investigated on a pilot plant level for a number of seafood processing wastewaters (shrimp, tuna and salmon). Full-scale applications have been limited to a Terminal Island, California, tuna cannery and a trout processing plant in Idaho.(46, 77) In Russia, excellent performance was achieved for a flotation cell with mechanically induced air treating fish processing effluent.(243)

d. Electroflotation

Electroflotation uses electric current (electrolysis) to generate tiny hydrogen and oxygen bubbles which are used to float the pollutants. Electroflotation is mechanically simpler and reportedly offers several other advantages over DAF. It produces less turbulence, which can tend to detach bubbles from the solids. In addition, destabilization of fine particles is achieved electrically, which reduces the quantity of chemicals required for effective removal. The major disadvantage of electroflotation is its excessive power requirement.

Flotation induced by electrolysis has been established as a potential pollution control technology for the food industry. Although some private testing has been performed on tuna cannery effluents, seafood plants have not yet adopted this technology on a full-scale level. A study has been funded by EPA to determine the applicability of electroflotation to the New England seafood processing industry.

It is important that the economics of this technology be considered in conjunction with its technical applicability. Recent input from the equipment manufacturers indicates the need to combine the principles of electroflotation with dissolved air systems to achieve hybrid systems for economic feasibility. Specific information relative to the basic design criteria and operating parameters (power and chemicals) is unavailable at present. However, a significant advantage identified for the hybrid system is the concentration of the floated material within the unit to about twice the normal levels.

It is apparent that electroflotation has not been demonstrated sufficiently to gain wide acceptance by the seafood processing industry. However, some information has been developed in Japan for treating fish wastewaters with electroflotation; the information provides an indication of the capabilities of this process.(82)

Flotation technology has been employed for treating a variety of food and seafood processing wastewaters throughout the world. For a given wastewater, available information indicates that waste removal rates are comparable for the various flotation methods. Efficiencies vary for different wastewaters, and the inherent advantages and disadvantages of each flotation method must be considered for the specific wastewater to be treated.

2. Advanced Technology. There are physical-chemical treatment processes which are considerably more sophisticated than flotation. However, these advanced systems are seldom considered by seafood processors, which generally employ simpler, less expensive techniques.

Possible applications have been identified for advanced treatment processes. For example, regulatory agencies in certain states are requiring treatment of the highly contaminated water, called bailwater, used to unload boats filled with menhaden. Plants of this nature are being encouraged to evaporate the bailwater to produce fish solubles which can be sold as a byproduct. If the waste stream can be concentrated before evaporation, then the costs of evaporation can be reduced. Some advanced technologies can fill this or similar needs, as described below.

a. Reverse Osmosis

Reverse osmosis is one advanced technology which can concentrate wastewater to produce a smaller volume for utilization, treatment or disposal. A schematic diagram of the process can be found in Figure 9. Wastewater and pure water are present on opposite sides of a semipermeable membrane, through which only extremely small particles (such as water molecules) can pass. High pressure is placed on the wastewater side of the membrane forcing water molecules through the membrane into the pure water side, Therefore, a concentrated solution remains on the wastewater side. The water which has been filtered through the membrane is usually pure enough to reuse within the plant for washdown or similar purposes.(1) If no pressure were applied, a natural process called osmosis would cause the pure water to enter the wastewater side of the membrane in an effort to equalize concentrations. The application of pressure reverses this process; hence the name reverse osmosis.

b. Activated Clay

Pollutants can be reduced significantly by passing bailwater through an acid-activated clay column.(124) This process is much like filtering water through sand. Since the spaces between clay particles are smaller than those between sand particles, this method is more effective than using sand. In addition, activation of the clay makes the adsorption of organics possible, thus reducing organic pollutant loadings discharged to surface waters.

c. Carbon Adsorption

Carbon adsorption columns work much like acid-activated clay columns. Granular carbon is generally used instead of clay. The carbon is specially treated (activated) to increase the surface area of the carbon granules and their ability to attract and hold or adsorb pollutant particles.

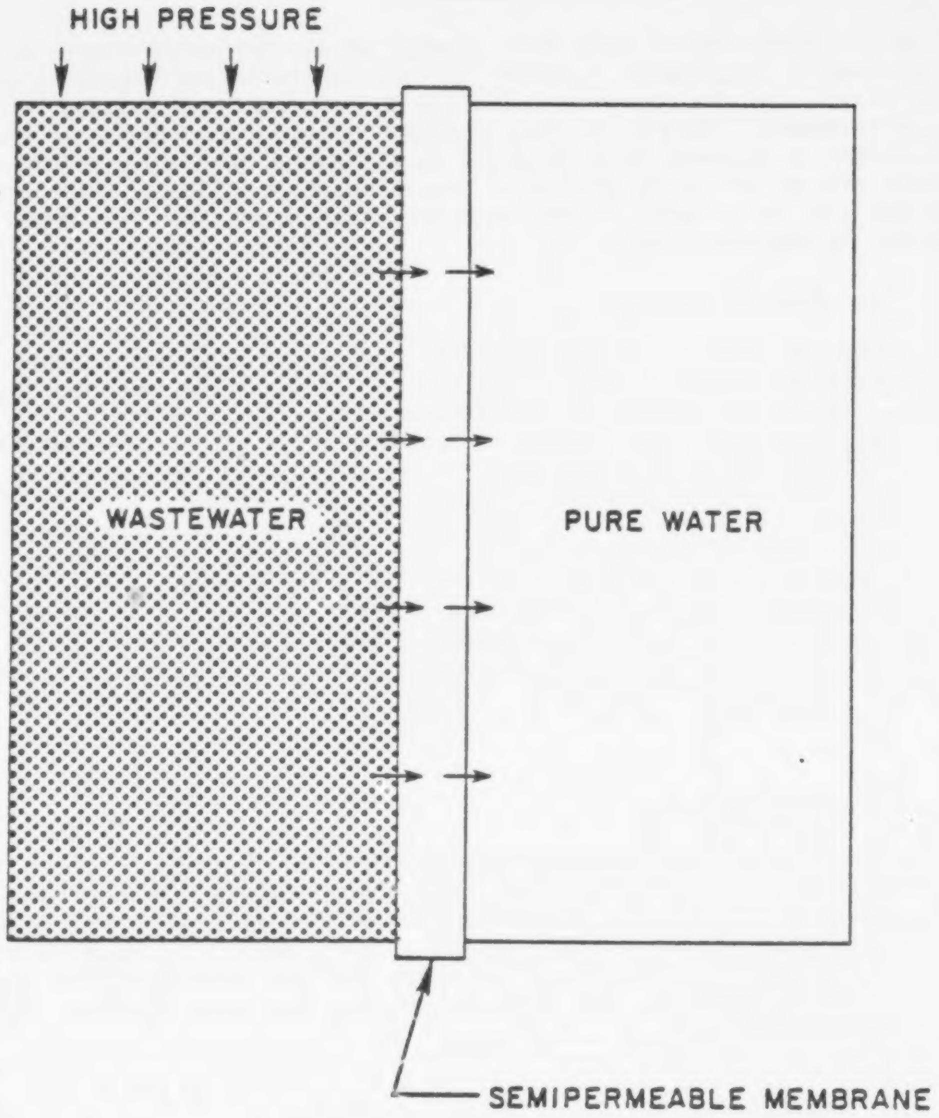

HIGH PRESSURE
WASTEWATER
PURE WATER
SEMIPERMEABLE MEMBRANE

Figure 9. Schematic diagram of a reverse osmosis unit.

d. Chemical Precipitation

Chemical precipitation can remove colloidal and suspended pollutants which have escaped other treatment schemes. Chemicals which are added to the wastewater combine with colloidal and suspended matter forming larger, insoluble particles. These heavy particles then settle to the bottom of a tank for easy collection. The principles of this technology are much the same as those for air flotation, except for the actual removal mechanism.

There are several other advanced technologies available for the renovation of wastewater, including ion exchange, filtration, electrodialysis, and chemical oxidation. However, such sophisticated methods appear unwarranted for the treatment of seafood processing wastewaters. Further, wastewater treatment beyond screening has not been encouraged for most processors.

In some instances, advanced wastewater treatment may be desired to produce renovated water for in-plant reuse. However, most processors generally do not presently have to worry about process water availability. Any reuse concept must meet the requirements of the Food and Drug Administration prior to implementation.

F. Land Treatment

The natural filtering properties of the soil and associated plant life can be exploited by pumping or spraying wastewaters onto the land. This approach for wastewater renovation is viable when sufficient and suitable land is available. Existing soil conditions largely determine the suitability of a site. For much of the industry, adequate land areas are either severely limited or unavailable.

Three general approaches have been developed for applying wastewater to selected land areas: 1) irrigation of a cover crop or vegetation; 2) allowing the water to run over the soil which is covered by vegetation; and 3) allowing the water to infiltrate the soil. Seafood processing effluents require pretreatment (a minimum of fine screening) before they can be applied to the land. Overland flow and infiltration-percolation alternatives will generally require substantial pretreatment to avoid operational problems.

For an irrigation system, wastewater can be distributed over a designated land area by spraying or flooding. Screening and/or sedimentation is required to prevent solids from plugging spray nozzles or clogging the soil. Ultimately, undesirable odors and system failure can result from soil clogging.

Several factors must be considered when applying seafood processing effluents to vegetated land. A primary concern is the total dissolved solids content of the effluent, particularly the sodium concentration. Large uses of salt water during plant operations could prove to be incompatible with irrigation technology. Evaluations relative to the specific wastewater requiring renovation and the site under consideration are recommended.

Climate is also important when considering irrigation systems. Irrigation systems located in cold climates may require storage facilities, depending upon the timing and length of the processing season.

A final concern is the determination of loading rates. Wastewater characteristics dictate whether hydraulic application rates or other factors will control. With a proteinaceous wastewater, such as that found within the seafood industry, nitrogen loadings must be considered. To prevent groundwater contamination, the soil and plant system must be able to fully assimilate the amount of nitrogen being applied.

There are two clam processing facilities in Maryland which employ spray irrigation for ultimate wastewater disposal. Prior to spraying, the plant effluent undergoes screening followed by sedimentation to minimize problems associated with nozzle clogging. At one facility, filtration has been contemplated as a further safeguard for the irrigation system. Spray irrigation has proven to be an effective disposal method for these facilities, which are essentially manual operations and generate relatively low volumes of wastewater.

G. Summary - End-of-Pipe Treatment Technology

With few exceptions, conventional wastewater treatment technologies have not been demonstrated on a full-scale level within the seafood industry. Seafood processors, in general, use simple techniques which require minimal land areas. The most basic and prevalent end-of-pipe treatment has been solids separation by screening. For industry segments which generate small volumes of low contamination wastewater, this approach, in conjunction with recommended in-plant control measures, should be sufficient to control waste discharges. Table 5 provides estimates of relative capital and operating costs for screening wastewaters generated by a few of these segments.

Physical-chemical treatment processes, such as sedimentation and dissolved air flotation (DAF), have been employed to a lesser extent. Biological systems and land treatment alternatives have not been widely adopted to date. Limited land availability in coastal areas is a major obstacle to implementing such systems. Technology more sophisticated than DAF has generally not been required on a federal, regional or state level.

TABLE 5

REPRESENTATIVE COSTS FOR SCREENING SYSTEMS
APPLICABLE TO SELECTED INDUSTRY SEGMENTS (126)

Wastewater Source	Plant Size (Tons/Day)	Total Daily Flow (Gal/Day)	Capital Cost ($1,000)	O & M Cost ($/Day)
Conventional Blue Crab	7	1,850	46	7
Alaskan Shrimp*	20	436,000	158	168
Hand-Butchered Salmon	15	12,300	46	16
Hand-Shucked Clam	25	29,000	47	19
Alaskan Herring Fillet*	50	150,000	100	112

*Includes building to house equipment and a barge for solids disposal.

It is possible to adopt aerated lagoon treatment as a means to control waste discharges from the catfish processing segment, which generally has greater land availability. Where sufficient land is available, the larger tuna processors could employ biological treatment. Relative costs to achieve secondary treatment for these two segments are displayed in Table 6.

Physical-chemical treatment processes are more applicable than biological treatment for most of the seafood industry. Physical-chemical processes can achieve high degrees of treatment using relatively small amounts of space. A disadvantage of the more advanced systems is the higher costs associated with equipment, chemicals, power, maintenance and other operational requirements. There is little practical application in the seafood industry for advanced technology such as carbon adsorption, filtration, reverse osmosis, electrodialysis, ion exchange and chemical oxidation due to the extensive pretreatment requirements. In addition, the high level of sophistication demands considerable operator training and attention

TABLE 6

REPRESENTATIVE COSTS FOR BIOLOGICAL SYSTEMS
DESIGNED FOR SELECTED INDUSTRY SEGMENTS (126)

Wastewater Source	Plant Size (Tons/Day)	Treatment System	Total Daily Flow (mgd)	Capital Cost* ($1,000)	O & M Cost ($/Day)
Farm Raised Catfish	15	Aerated Lagoon	0.051	172	90
Tuna	400	Aerated Lagoon	1.07	540	490
Tuna	400	Activated Sludge	1.07	1,900	750

*Assumes sufficient land area is available.

Flotation schemes appear to have the greatest potential for effluent treatment. The effectiveness of non-optimized dissolved air flotation systems has been demonstrated on a full-scale level at several tuna canneries throughout the United States and its territories. Improved removal efficiencies should be achievable under optimal conditions. Optimization of dissolved air flotation systems involves adjusting the pH of the wastewater to the isoelectric point of fish protein followed by the addition of the chemicals needed for coagulation and floculation to achieve the maximum removal of suspended and colloidal particles. Minor pH adjustments may be required prior to discharging the treated effluents either to a subsequent treatment process or receiving waters. For other segments of the seafood industry, the capabilities of optimized DAF systems have been demonstrated in the United States and Canada utilizing federal grants. Information is available for the treatment of wastewaters resulting from the processing of crab, shrimp, tuna, salmon, bottomfish, sardine, herring, and oyster. Data generated in other countries supports the application of flotation technology to the seafood processing industry. Table 7 provides cost estimates for the installation of DAF systems at plants within selected industry segments. These estimates are based on flow information which reflects the adoption of in-plant measures applicable to the specific segment.

TABLE 7

REPRESENTATIVE COSTS FOR DAF SYSTEMS APPLICABLE TO SELECTED INDUSTRY SEGMENTS (126)

Wastewater Source	Plant Size (Tons/Day)	Total Daily Flow (mgd)	Capital Cost* ($1,000)	O & M Cost** ($/Day)
Southern Non-Breaded Shrimp	10	0.107	230	355
Mechanized Salmon	35	0.119	220	365
Mechanized Bottomfish	30	0.092	245	360
Sardine	70	0.117	200	170
Herring Fillet	120	0.359	410	870

*Assumes screens are in-place.
**Includes chemical costs for optimization.

Although similar wastewaters are generated by Alaskan operations, the installation of DAF equipment has been found to be impractical in view of the geographical and climatic conditions. The availability of required chemicals and skilled labor for optimized operation is also restrictive. Plants in most processing areas are physically confined or constructed on piles over water. The expense of providing additional space on a wharf and a building to house the equipment does not appear warranted. Therefore, in-plant modifications in conjunction with screens are considered applicable for these segments of the industry.

Other physical-chemical processes may be feasible for selected waste streams which are highly contaminated or represent a potential for reuse. Case-by-case evaluations are required to justify the implementation of this treatment approach.

CHAPTER 4

SEAFOOD WASTE UTILIZATION AND DISPOSAL

I. BACKGROUND

A. Solids Generation

Waste management practices applicable to the seafood industry generate two types of solids: wastes captured during actual processing; and materials which escape into the plant effluent for later capture by waste treatment facilities. In general, the most economical way to reduce the total amount of waste solids requiring disposal is to capture unused raw materials in-plant, and to process them into marketable secondary products. Once the raw materials have entered the waste stream, they are generally more expensive to recapture. Furthermore, the production of marketable byproducts using materials separated from the waste stream are more complex and inherently more costly. The potential markets for these byproducts are more limited than those for consumable secondary products manufactured in-plant.

Both types of solids will vary in quantity and character depending on the location of the facility, species processed, time of year, and waste management practices. Historically comprehensive in-plant water and waste management practices have not been utilized in this industry. As a result, the need for identifying methods for recovering materials for subsequent utilization has been minimal.

1. In-Plant Solids Generation. Waste fish solids, processing scraps and meat fragments which remain after processing of a primary seafood product can be collected and processed into a variety of secondary products and byproducts such as petfood, fish meal and animal feed supplements. By collecting these solids at their source, the volume of solids entering the central waste stream can be significantly reduced. Relatively simple management practices are available to approach total utilization of the raw material; however, these practices have not been widely implemented in some segments of the seafood industry. Although methods to recover raw material are relatively simple, the adoption of the total utilization approach is subject to economic considerations, market availability, and governmental regulations.

In some segments, water is used to convey raw materials from boats to storage facilities inside the processing plants. In-plant systems also rely heavily on hydraulic conveyance. As a general objective, the industry needs to become more aware of ways to reduce water use through alternative dry handling systems. Attention to limiting water use could result in better recovery of in-plant solids and reduced discharges of potentially useful materials as waste.

2. End-of-Pipe Treatment. Wastewater from most seafood processing operations is not subjected to high levels of treatment. Most common are simple solids separation systems, usually screens, which physically separate larger solids from the waste stream. These separated solids can be collected for byproduct manufacture, or they can simply be transported to a disposal site. Because there are no chemicals added to the screened solids, they are more acceptable for byproduct manufacturing than solids captured using higher levels of tech-

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nology. The available alternatives for disposal are also more numerous. Options include the manufacture of animal feeds, aquaculture nutrients, agricultural fertilizers, landfilling and barging for deep sea disposal.

Beyond screening, which is prevalent in the seafood industry, some plants employ sedimentation, dissolved air flotation (DAF) and biological treatment systems for additional reductions of waste constituents in the screened effluent. Technologies more sophisticated than DAF have generally not been mandated by the environmental regulatory agencies, thus there is little demonstrated application of full-scale wastewater treatment by the industry. Simple sedimentation has been adopted by some shellfish (clam and oyster) processors for the removal of sand, silt and shell fragments. Landfilling of the separated solids is commonly employed.

Dissolved air flotation (DAF) has received some attention for its application to the seafood industry. It has been used successfully by some of the major tuna processors, and has seen widespread use by related food industries such as poultry processing, red meat packaging and rendering. The solids which are skimmed from the surface of the flotation unit are than directed to a collection vessel. System operations can be aided by chemical coagulants and flocculents at an optimum pH. Chemical additions are necessary to provide adequate DAF performance; however, their use inhibits the conversion of the resulting sludge (float) into byrproducts. Float characteristics in relation to the requirements of the Food and Drug Administration for animal feeds will be discussed later in this section.

DAF sludges, or the skimmed solids, are water-laden, typically consisting of 5 to 20 percent solids. The technology is available to dewater this semi-liquid material to approximately 30 percent solids with a coincident two-thirds volume reduction. The decision to do so would depend on the adopted disposal method and the inherent economics. For example, liquid DAF float can be hauled to a land application site and sprayed on the ground or injected beneath the soil surface, whereas dewatered float is limited to surface spreading.

DAF sludge contains valuable nutrients, plus oil and grease which require care when used in any land application scheme. Alum is often used to aid the flotation process; thus significant concentrations of aluminum may be present in DAF float. The presence of salt (and sodium) must likewise be considered in terms of the toxicity to cover vegetation and effects on the soils at the selected disposal site.

B. Current Solids Disposal Practices

The Alaskan seafood industry differs in many ways from operations in the remaider of the United States. Therefore, the discussion relating to current solids disposal practices will segregate Alaskan processors from those in the contiguous states.

1. Contiguous United States. Among the solids disposal methods practiced by seafood processors in the contiguous United States are: a) secondary utili-

zation; b) byproduct manufacturing; and c) land application (including landfilling). These methods are discussed individually below.

a. Secondary Utilization. Waste materials from seafood processing can be converted into secondary products both to improve total resource utilization and to reduce or offset the cost of waste management. The most common examples of secondary products from finfish are fish sticks and fish cakes, which are comprised of deboned or extruded flesh.

Fish solids can be manually accumulated in totes or bins along the production line, which is an effective step in preventing gross solids from entering the waste stream. Collection troughs can also be designed to prevent the solids from coming into contact with the floor. Other methods of collecting the solids include mesh-type conveyors or coarse screens. Specific fish parts can be directed to designated area for subsequent processing into secondary products. Salmon roe, for example, can be separated, graded, cured, boxed and marketed for human consumption. Deboned fish flesh can and has been processed into marketable commodities such as breaded fish cakes for human consumption.

b. Byproduct Manufacturing. More prevalent, however, is the production of byproducts such as animal food and feed additives. Tuna and salmon operations have successfully converted wastes into petfood which can realize a profit. In some cases, the preparation of fish wastes as petfood is accomplished as part of a line which includes other primary ingredients such as beef and chicken parts. Some seafood plants have on-site byproduct facilities. For example, major tuna processors operate facilities to produce meal and oil from fish scraps and cooker water generated during canning activities. Other processors collect the waste materials and ship them to remote off-site byproduct plants.

Finfish processing wastes have also been used as bait, particularly within the sardine, salmon and halibut processing segments.

The proteinaceous wastes from seafood processors can be converted into a number of useful byproducts. For example, the reduction process, which is employed by tuna canneries, yields a protein meal which can be used as an animal feed supplement. In some instances, the required equipment has been installed on-site at individual processing plants; however, facilities are available in specific geographical areas to serve several food processing operations.

Because of the intermittent production schedules typical throughout most of the seafood industry, on-site reduction facilities have not been widely incorporated at individual processing plants. To make the fullest possible use of such reduction facilities, some of the larger tuna canneries supplement tuna scrap processing with anchovy reduction at appropriate times of the year.

Unprocessed wastes have been used to produce fish feeds and fertilizer. Fresh or frozen fish solids, including catfish offal, have been incorporated into an acceptable diet for farm-raised catfish.(85, 139) In addition, shrimp wastes have been used as a feed supplement for aquaculture for pigmentation.(113). The solids generated during shrimp and crab processing have significant value where a nitrogen-phosphorus fertilizer is required.(38)

Of the various byproducts that can be produced from shellfish wastes, one of the most interesting is chitin (pronounced "ky'tin") and its derivative, chitosan. It is a straight chain polysaccharide polymer closely related to cellulose. Chitin is the second most abundant organic compound on earth, yet its properties and applications have only recently gained significant attention.

The technology exists to isolate chitin from protein in shellfish wastes and to produce chitosan, a commercially interesting derivative. The resultant natural compound has been found to have applications as a coagulant in wastewater treatment.(14, 15, 16, 18, 19, 20, 22) Additional uses include additive in paper making and textile dyeing; film for membranes used in electrodialysis (e.g., desalination); thickening and emulsifying agent; and a wound healing accelerator. Studies have also shown that chitinous materials can be used as animal feed supplements. (18, 22) The digestability and nutrient value for ruminating animals has been established; however, the investigators noted that additional investigations are necessary to gain Food and Drug Administration approval of chitosan as a food additive.

These and other byproducts will be discussed more fully in the Section III of this chapter, entitled "Byproduct Manufacturing."

c. Land Disposal. Secondary product and byproduct manufacturing account for only a fragment of the total waste management practices available to the seafood industry. In addition to the gross solids that can be incorporated into marketable products, there are other processing residuals, such as DAF float and biological sludges, which are usually disposed of on land. Disposal is accomplished by applying the material to land to propagate a cover crop or by burial at a landfill site.

Among the factors that must be considered when applying seafood processing wastes to the land are: 1) nitrogen content; 2) oil and grease content; 3) sodium concentrations; 4) salinity; and 5) odor potential. Nitrogen content and odor control are also considerations for landfill operations. The moisture content of the sludge is an important characteristic when evaluating landfill sites.

Surface spreading and soil injection are two alternative methods for applying waste sludges to the land. Both methods require suitable site, weather conditions, soils, drainage and other factors, not the least of which is careful management of the land application operation.

Two approaches are available for landfilling waste treatment residuals: the cell method and the trench method. Selection of the appropriate method is based on site considerations. Either method can provide the environmental control for sludge disposal when properly managed.

The above discussion of solids disposal practices - encompassing secondary products, byproducts and land disposal - has offered a general perspective of the seafood industry. However, a major segment of this industry is located in Alaska, where some of the alternatives discussed above may not be applicable. Land disposal for example, is not feasible for most areas in Alaska. Therefore, solids handling practices for Alaskan processors are discussed separately below.

2. Alaska. Seafood processing plants in Alaska are dispersed all along the Alaskan coast, from the Aleutian Islands to the city of Ketchikan and the southeastern panhandle. Some of these plants are isolated; others are located in processing centers which support several seafood operations. The processing centers do not necessarily coincide with population centers. For example, Anchorage is the most populated area in Alaska; but it supports just one salmon cannery and a cold storage facility. The largest seafood processing center (in terms of the number of plants) is in the city of Kodiak on Kodiak Island, which has approximately three percent of the population of the Anchorage area.

Although the conditions encountered throughout Alaska will vary with the specific location, they are significantly different from those occuring in the contiguous United States. Some unique factors influencing the handling and disposal of waste materials are labor availability, weather conditions, geography, geologic and soil conditions, and relatively high costs associated with construction and transportation activities. Combinations of two or more of these factors tend to limit the alternatives available to seafood processors for the disposal of waste treatment residues.

A review of the general soil characteristics and geologic conditions for selected processing areas indicates that land disposal of seafood solids should not be adopted as an industry wide alternative in Alaska. Input from the municipalities reinforces this conclusion. Surface spreading or subsurface disposal of solids for crop fertilization is limited to agricultural areas, which are not prevalent in Alaska. Therefore, it appears that byproduct recovery and barging are the two options which are technically feasible for Alaskan seafood processors.

In evaluating the Alaskan seafood processing industry, the U.S. Environmental Protection Agency (EPA) has differentiated between remote and non-remote areas. Solids handling practices, particularly with respect to secondary product and byproduct manufacturing, differ substantially for remote areas and specific non-remote locations.

a. Non-Remote Areas. Under the original philosphy, non-remote areas were selected as those which have significant populations and/or several processing facilities in a definitive geographical area. These included Anchorage, Cordova, Juneau, Ketchikan, Kodiak and Petersburg. In these areas, water quality considerations require more rigorous pollution control efforts. These locations generally offer more dependable road and ferry transportation, readily available power, and access to larger numbers of workers demanding lower wages. These and other economic advantages, such as the opportunity for cooperative approaches to waste management, open some seafood waste management alternatives, including reduction facilities, which are not available to more remote processing plants.

Three Alaskan areas - Kodiak, Petersburg and Seward - have reduction facilities which convert fish processing wastes to useful byproducts. Each facility has the capacity to accommodate materials generated by local processors. Through contractual agreements, the largest reduction plant, which is in Kodiak, is devoted to serving the 15 processors in the immediate area. Because of inherent inefficiencies, this plant has been operating with subsidies from the processors to serve as a convenient, local waste disposal facility. The facilities in Petersburg and Seward were originally intended to be economically self-sufficient in producing fish meal and oil from whole fish and processing wastes generated in their respective geographical area. However, neither facility has been operated at full capacity on an annual basis due to the limited availability of raw material. This limited availability results from the lack of waste management by area plants. Because the Seward and Petersburg reduction plants have excess capacity, they will generally accept processing wastes transported from outside the immediate area. In the past, both plants have received and processed wastes from processors located more than 100 miles away. However, this practice has been generally discontinued because the plants have chosen to grind and discharge their wastes in view of economic considerations.

In the absence of on-site or nearby waste processing plants, the collection and transport of waste materials to a plant which manufactures petfood represents an alternative waste solids handling procedure. Alaskan salmon canneries, for example, have collected, packaged and frozen salmon heads for shipment to Seattle petfood operations. These salmon processors are then allowed to simply grind their remaining waste solids for discharge to local receiving waters. Since they choose to collect and ship a portion of their wastes to Seattle suggests that some economic advantage is realized through byproduct manufacturing, despite the transportation costs.

A final disposal option currently available to Alaskan seafood processors is the collection of gross and screened solids for barging to deep water dumping sites. Every processing area has a designated dumping site, usually within a five-mile distance of the processing facility.

b. Remote Areas For the remote Alaskan fish processing plants, there are generally only two viable waste solids disposal methods: grinding and discharge to local receiving waters; and barging to deep sea dumping sites. The vast majority of processors in these areas have elected to grind wastes for discharge.

C. Future Considerations

Solids handling and disposal practices which have been adopted by most segments of the seafood industry, in some cases are adequate but are generally unsophisticated. With the exception of the tuna and fish meal processing segments, there has been limited implementation of in-plant waste management practices or secondary or byproduct manufacture. Most demonstrations of improved in-plant water and waste management have resulted from either a gross pollution problem or from readily apparent and immediate economic advantages for more complete raw material utilization.

As the environmental responsibilities of various segments of the industry become better defined, it can be expected that considerable progress can be made toward reducing waste discharges to receiving waters. The most economical way to achieve immediate reductions in processing waste discharges is through improved in-plant waste materials handling. In particular, the conversion from fluming to dry handling of waste materials will yield improved segregation of useful raw materials for possible secondary or byproduct manufacturing. At the same time, dry handling systems, recycling, and general reductions in water use by the processors will result in effluent volume and waste load reductions.

The operation of screening equipment to supplement in-plant control measures at Alaskan processing plants will create a need for options in disposal/utilization. Meanwhile, in the contiguous United States, DAF and biological treatment systems have been found to be applicable to a number of industry segments. As these treatment facilities are installed and placed on line, they will produce increasing volumes of solids requiring some means of disposal. Among the alternatives which are expected to receive increased attention are:

- secondary product development;
- byproduct manufacturing;
- chitin/chitosan production; and
- other disposal methods.

These topic areas are addressed in the remainder of this chapter.

II. SECONDARY PRODUCT DEVELOPMENT

To differentiate between secondary products and fish processing byproducts, this discussion will focus on secondary products which are suitable for human consumption. Byproducts will include all other manufactured products and derivatives which are not directly consumed by man; e.g., fish meal, petfood, bait, fertilizer, chitin/chitosan, etc.

The processing of secondary products requires separation of raw materials (i.e., gross solids) at their source. Means of accomplishing this necessary first step will be discussed, followed by a review of some of the major secondary products which can be produced from finfish wastes and shellfish wastes, respectively.

A. Separation of Gross Solids at Source

Conversion of waste materials into secondary products fit for human consumption generally requires the collection of leftover fish parts during production of the primary product. The simplest approach is manual accumulation of gross solids in totes or bins. Several facilities which hand butcher salmon have adopted this method to prevent gross solids from entering the waste stream. Conventional bottomfish is another industry segment which could adopt manual separation of fish parts for subsequent utilization.

Dry handling of all waste materials is desirable in terms of pollution control. Belt conveyors are used throughout the food industry for this purpose. Meal plants operated by or in conjunction with tuna canneries, employ belt or screw conveyor systems to transport the tuna wastes from the cleaning tables to the meal plant, thereby avoiding the use of water. This operation facilitates handling of the waste material during separation and processing at the meal plant.

To develop secondary products using gross solids, it is essential that the raw material be prevented from coming into contact with the floor. Various facilities have installed devices which prevent waste solids from hitting the floor and ultimately entering the waste stream. Coarse screens and mesh-type conveyors can help achieve this goal, as well as reducing solids loading to fine screens or other end-of-pipe treatment equipment.

Although the equipment available to collect the raw materials for secondary product development are relatively uncomplicated, the housekeeping and other practices of the processors which produce secondary products must be carefully managed. Great care is required to produce from once-neglected wastes a commodity now aimed at human consumers.

By collecting gross solids as described above, a seafood processor may achieve three objectives: 1) more complete utilization of raw materials; 2) the development of a secondary product which can produce additional income; and 3) a reduction of waste volumes requiring subsequent disposal. The economics of secondary product development depend on plant location, species processed, availability of equipment and market conditions for the secondary product(s). As the cost of waste disposal increases, so does the incentive for secondary product manufacturing.

Examples of the secondary products manufactured by finfish and shellfish processors are described below.

B. Secondary Products from Finfish Wastes

After fish parts have been collected in a specified area, they can be subjected to a number of secondary processing alternatives. A model example of such a product is salmon roe. Conventional processing equipment has been modified and handling practices developed to facilitate roe separation from mechanically butchered salmon. Subsequently, the roe is graded, cured and boxed for shipment to Japan. In recent years, salmon roe has become a secondary product which is too valuable to be discarded by canning and freezing operations.

Other fish parts can be isolated and manufactured into secondary products. Finfish processing plants are capable of producing fish flesh which has been deboned. Flesh separator machines are available which can recover 37 to 60 percent of minced flesh from various species. In comparison, the conventional filleting techniques only yield a primary product which ranges from 25 to 30 percent flesh. The machine separator squeezes the relatively soft muscle tissue through a rotating perforated drum. Skin and bones mat on the outside of the drum and are scraped off into a waste chute. The minced fish muscle may be used in fabricated foods such as pasteurized spreads, frankfurters, fish cakes and fish loaf.

Implementation of deboning operations requires a considerable capital investment and an established market. At least one salmon cannery in the Puget Sound area determined that the capital expenditures were justified in order to produce a deboned salmon commodity from materials which are discarded as wastes by most facilities. Although every salmon cannery cannot be expected to install a similar line, the economic feasibility should be explored by individual plants. Other finfish operations also have the potential for generating deboned or extruded products. Battering and breading operations may follow to generate marketable commodities such as fish cakes.

C. Secondary Products from Shellfish Wastes

Shellfish, like finfish, can be subjected to mechanical flesh separation. In Canada, for example, flesh separators have been used on lobster bodies to produce salable products. Fabricated shrimp products can likewise be produced in this manner. However, only isolated references to such applications can be found in the literature.

Secondary products can also be recovered from isolated waste streams. A good example is the development of a product similar to clam juice from minced clam washwater. This process, which was recently investigated by a Sea Grant Institution, has been found to be advantageous both in terms of economics and water pollution control, achieving a significant reduction in the BOD_5 load of plant effluent.(66) Further processing of the product into a dry flavor ingredient has also been demonstrated for the East Coast surf clam processor. (74)

III. BYPRODUCT MANUFACTURING

The manufacture of fish processing byproducts includes a wide variety of products having applications other than human consumption. The general types of wastes incorporated into such products are introduced below, followed by a more detailed accounting of the processes and end-products involved with byproduct manufacturing.

A. General Ingredients

Seafood processing wastes can be categorized into four general types: gross solids collected from the production line; screened solids captured prior to effluent discharge; dissolved air flotation (DAF) sludge; and biological treatment sludge. All of these wastes are characterized by significant protein and nutrient contents. Some of the more common byproducts which can be manufactured from these wastes are described below.

B. Gross Solids

1. Finfish Wastes. Gross solids recovered from finfish processing operations represent a significant value in terms of total product utilization. Tuna processors have long recognized the economic advantages of recovering blood meats and off-color parts of the fish for incorporation into petfood. Some of

the tuna processors operate petfood canning lines in conjunction with their primary processing activities.

Some salmon processors have collected the larger solids and transported them off-site to petfood facilities. These petfood plants may receive waste fish material from more than one processor. To date, this option has been adopted by only a limited number of processing plants.

The cost of equipping, operating and marketing a petfood line has limited the number of on-site petfood operations at seafood plants. Generally, only the larger tuna plants which process seafood year-round have installed on-site petfood lines. One salmon cannery has incorporated waste fish solids into petfood containing other ingredients. But for the most part, non-edible fish parts which are retained by plants are transported off-site for subsequent utilization or disposal. The operation of a petfood plant serving a regional group of primary seafood processors may offer a better economic situation than single, on-site operations. Nonetheless, small on-site petfood operations which handle only fish wastes can reduce waste volumes requiring disposal while offsetting some of the waste handling costs.

Unprocessed fish scraps from sardine, salmon and halibut processors are often collected and sold as bait. From sardine packing tables, for instance, the heads and tails are conveyed to a chum truck. The major use of these materials is as bait by lobster fishermen, who purchase the waste. On the West Coast, heads removed from salmon and halibut facilities can be used for bait as well. This practice is also applicable to Alaskan processing areas. Because fishing is a seasonal activity, demand for bait fluctuates. When it is low, the fish wastes can be transported to byproduct manufacturing facilities which may generate fish meal and oil using a reduction process.

The reduction process parallels rendering in other food industries. As shown in Figure 10, reduction is basically a cooking process followed by drying and milling to produce a dry fish meal product. Other byproducts include separated oil and solubles (the product of stickwater or press water evaporation). In some cases the solubles, which contain a high level of dissolved matter, are recycled to the drying operation to increase the capture of protein in the meal. The protein-rich fish meal is generally used as an animal feed supplement. Oil which is separated during the processing of finfish wastes represents another salable byproduct. Markets exist for both fish oil and solubles. Potential uses included nutrient supplements for mushroom growing. Solubles can also provide supplemental nitrogen for composting agricultural manures.(53)

As with the operation of on-site petfood plants, the operation of on-site fish meal production equipment is limited in an industry which does not feature consistent, year-round production. Waste material supply fluctuations have hurt the profitability of reduction plants, and only a few of the larger processors produce their own fish meal. Even the regional fish meal installations, such as those in Petersburg and Seward, Alaska, have failed to operate at full capacity because of raw material supply problems. It is anticipated however, that the increase of bottom fish production in Alaska and the contiguous United States will supplement current raw material supplies, especially during low activity periods.

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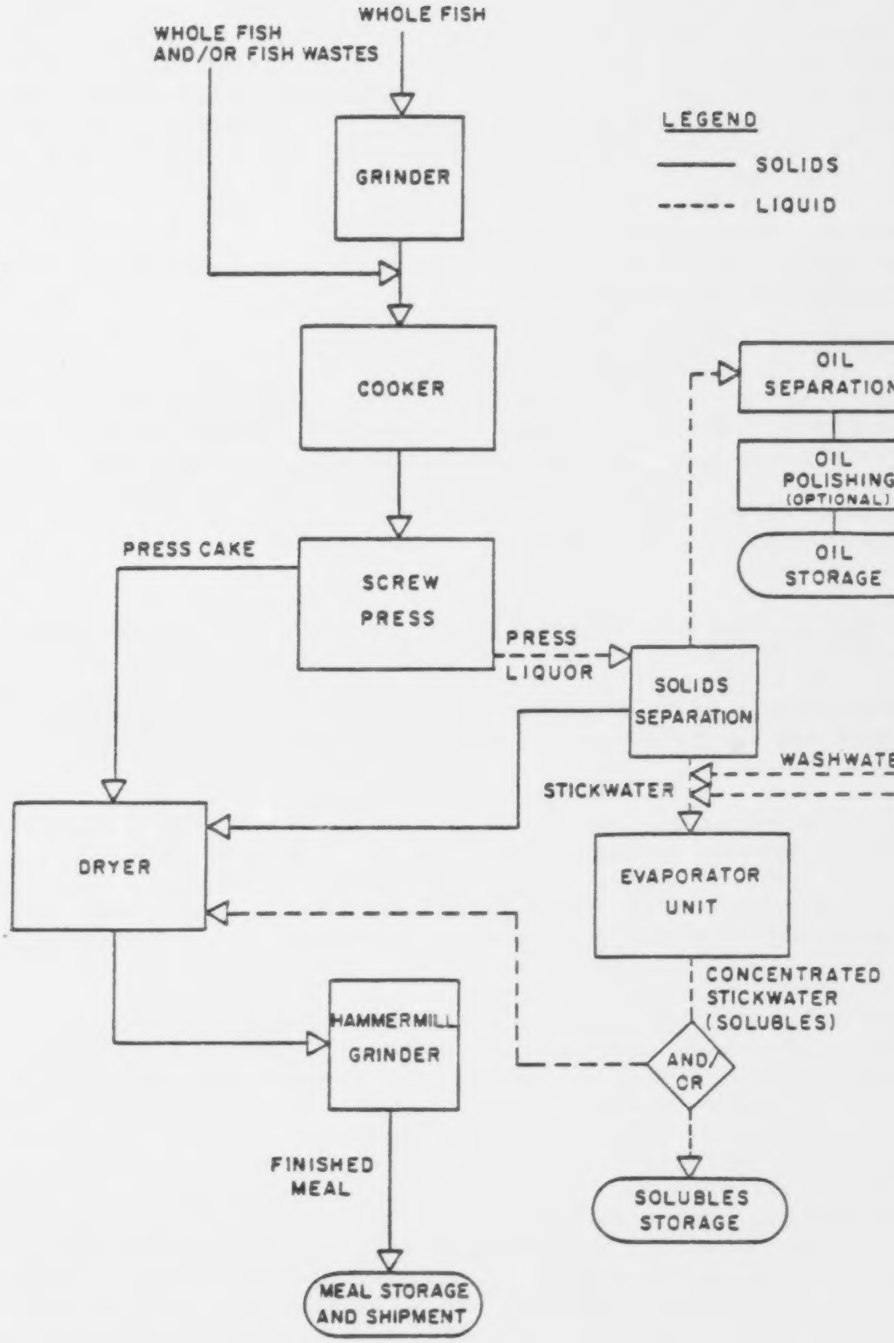
WHOLE FISH
WHOLE FISH AND/OR FISH WASTES
GRINDER
LEGEND
SOLIDS
LIQUID
COOKER
OIL SEPARATION
OIL POLISHING (OPTIONAL)
OIL STORAGE
PRESS CAKE
SCREW PRESS
PRESS LIQUOR
SOLIDS SEPARATION
WASHWATER
STICKWATER
DRYER
EVAPORATOR UNIT
CONCENTRATED STICKWATER (SOLUBLES)
HAMMERMILL GRINDER
AND/OR
FINISHED MEAL
SOLUBLES STORAGE
MEAL STORAGE AND SHIPMENT

Figure 10. Process schematic of a conventional fish meal plant with solubles production.

Some of the supply problems can be avoided by producing fish silage, a liquid product made by adding acid to fish parts and allowing enzymatic digestion to occur. Simple equipment can be used to make small amounts of silage from intermittent raw material supplies. More expensive equipment is needed to manufacture large quantities, but the required labor skills are minimal when compared to fish meal production. Liquefaction caused by naturally occurring enzymes in the presence of acid results in a versatile, high-quality protein feedstuff which will keep for long periods. The silage process offers additional advantages over meal production: 1) it is relatively odor-free, and 2) it alleviates a serious problem of liquid waste disposal. The University of Washington, among others, has been researching silage production. In Europe, silage production was developed in Sweden in 1930; Denmark and Poland now have well-established industries.(54)

The stability, protein content, usefulness and economy of production associated with the product are matched by pollution control advantages. At the present time, silage is fed in liquid form to pigs and cattle. It is a bulkier protein product than meal. Accessible, nearby markets are therefore desirable to minimize the costs of storage and transportation. However, it is possible to dry the silage to accomplish long-term storage or transportation.(54) In any form, the stability of silage is a distinct advantage to seafood processors when compared to other byproducts.

2. Shellfish Wastes. Gross solids from crab and shrimp operations, like those from the finfish plants, are often converted into protein meal products. Shells can be ground and dehydrated, then processed into a meal yielding protein contents of 30 to 40 percent by weight. Full-scale production of meal from crab and shrimp wastes has been accomplished in Alaska and the contiguous United States.

Among the problems encountered in producing shellfish meal are a highly odorous drying process, a high calcium content (up to 40 percent by dry weight), and lower protein content than fish meal. The environmental problems may require installation of expensive pollution control equipment; yet the shellfish meal may be worth only about a one-third the wholesale value of fish meal.

A relatively new, but simple concept was recently introduced to improve the economics of converting crustacean wastes to marketable byproducts.(112) The approach of mechanically separating the protein from the inorganic material (shells) to allow separate processing of the fractions was found to have several advantages. The advantages identified include: 1) production of a proteinaceous meal which approaches the market value of fish meal; 2) isolation of the shell fraction which either can be utilized for the manufacture of chitin/chitosan, or pulverized to generate a material with desirable properties; 3) reduction of the volume of shell material subjected to the drying operation which can be highly odorous and require the installation of costly air pollution control equipment; and 4) availability as a recovery method for isolated locations and where dehydration of crustacean wastes is economically unattractive.

Other shellfish waste byproducts include the following:

- use of crab and shrimp wastes as an agricultural fertilizer, particularly where a nitrogen-phosphorus fertilizer is required;
- use of shrimp protein as a food supplement for aquaculture (salmon and trout rearing) to achieve desired pigmentation;
- peptone production from enzymatic digestion of shrimp wastes;
- direct animal feed (e.g., clam bellies for swine); and
- production of chitin and chitosan from crab and shrimp wastes.

Among the shellfish byproducts listed above, chitin/chitosan production and utilization appears to offer the greatest promise for crab and shrimp wastes. This alternative is specifically addressed later in this chapter, as Section V, "Chitin/Chitosan Production from Shrimp and Crab Wastes."

C. Screened Solids

Fish wastes which are not recovered as gross solids enter the processing waste stream and are captured by end-of-pipe treatment facilities. Among seafood processors, screens are generally the first and most universally applied treatment mechanism. Solids trapped by the screens can be collected and used in the manufacture of byproducts, either alone or in combination with gross solids recovered in-plant.

1. Finfish Wastes. Screenings from finfish processing plants can be processed into fish meal and oil with or without the addition of gross solids. The screenings, like the gross solids, are high in protein and nutrient value and, can be converted to byproducts such as animal feeds, fish silage, nutrients, fish food (often in pellet form), and agricultural fertilizers. The screening process does not require chemical additives, thus the byproducts which can be generated from them approximate those described above for the gross solids.

2. Shellfish Wastes. Screens used by the shellfish processors capture solids which can be incorporated into most of the same byproducts that were identified earlier for gross solids. Again, the mechanical separation of proteinaceous material from crustacean shells for separate processing into byproducts offers several advantages. The most interesting byproduct appears to be chitin and its derivative, chitosan. In addition, peptones have been extracted from screened shellfish wastes to produce a medium for microbiological growth which can be utilized in laboratory investigations.

D. Dissolved Air Flotation (DAF) Sludge

1. General. Fewer than ten seafood plants (all tuna) operate full-scale DAF systems on a continuous basis. However, DAF systems have been extensively used by other related food industries, such as meat, poultry and rendering,

having waste loads comparable to those generated by the seafood industry. Experiences relative to handling and disposing of the resulting sludge in these particular segments of the food industry will be discussed as they apply to seafood processors in general.

2. DAF Float Characteristics. The dissolved air flotation process removes suspended solids, oil and grease from wastewater. A typical DAF unit comprises a tank, an air retention vessel, chemical feed equipment and a surface skimmer. Suspended solids, oil and grease which become attached to air bubbles and float to the surface, are then skimmed from the water surface and collected as sludge, or "float."

The volume of float produced by a DAF system generally approaches 1 or 2 percent of the total wastewater throughput. The float is mostly water, varying from 5 to 20 percent solids content (by weight) and 0.2 to 3 percent oil and grease (by weight). The composition of the float from a specific DAF unit will depend on the characteristics of the wastewater being treated, as well as numerous operating parameters of the DAF system. Among the operating parameters of greatest concern are the rate of air introduction (as compared to the rate of solids entering the system) and the types and amounts of chemicals added to the system to make it operate more efficiently.

The removal of colloidal constituents can be aided by adjusting the pH to the isoelectric point of fish protein (pH 4.5 to 5). The addition of chemicals for coagulation and flocculation of suspended materials also improves overall DAF performance. Coagulant aids include lime in addition to trivalent salts such as aluminum sulfate (alum), sodium aluminate and ferric chloride. Other flotation aids such as lignosulfonic acid (LSA) have been investigated in various combinations with anionic and cationic polyelectrolytes (polymers) to improve pollutant removals. From the information available, it appears that chemical additions are needed to provide acceptable DAF performance.

Chemical additives such as the trivalent salts and polymers remain in the DAF float that is collected. Also present is salt from any salt water used in the seafood processing operation. These substances limit the potential uses of the DAF float which, like other solids from the seafood industry, contain significant levels of nutrients and proteinaceous material. The approval of these chemicals by FDA is required to produce animal feed supplements from chemically coagulated float. At present only one coagulant, LSA, has been approved by FDA for use in animal feeds. Contact with FDA has indicated that no additional applications have been submitted by seafood processors for approval of other coagulants.

3. DAF Float Handling. Unprocessed DAF float is semi-liquid in nature, and would be handled as a liquid. However, this is not always convenient or desirable. Although the seafood industry has only limited experience in handling DAF float, some of the related food industries which use DAF treatment have found that further processing of the float is required to make the material more suitable for disposal or utilization. Among the processes which are used to modify the float are the following:

- thickening - to further concentrate the sludge, thereby reducing its volume;

- stabilization - to reduce putrescible and pathogenic nature of the sludge and make it easier to dewater;
- conditioning - to obtain further stabilization and further increase dewaterability;
- dewatering - to convert the sludge into a moist cake (more than 20 percent solids) which can be more easily handled and transported; and
- drying - to remove essentially all water, thus obtaining a relatively dry material for utilization or disposal.

Use of any of the sludge treatment methods outlined above would depend on the objectives sought for disposal or utilization of the end-product. For example, stabilization is usually required if the sludge is to be landfilled in an environmentally acceptable manner. If landfill site limitations or transport costs are a problem, dewatering may be used to reduce the volume of material requiring disposal.

Because of the limited number of applications for this technology, the seafood industry has very little experience handling the float. The most advanced approach adopted by a tuna cannery consists of centrifugal dewatering followed by landfilling. Surveys of meat packers, poultry processors and renderers show that DAF float can be successfully dewatered using gravity phase (liquid/solids) separation or centrifugation. Many of the processors contacted subject their DAF sludge, which in some cases contain chemical coagulants, to an on-site or nearby rendering process.

4. DAF Float Utilization. The trend toward utilization of DAF float can be expected to increase as land disposal sites become more scarce and environmental restrictions increase. Despite the presence of coagulants, byproduct development should be pursued in lieu of burying the float. The use of alternative chemical coagulants, such as lignosulfonic acid (LSA), can allow DAF float to be processed into a salable proteinaceous byproduct which can be approved for animal feed. This process has been successfully adopted by at least one meat packer, the Sterling Colorado Beef Company, in the United States.(59) Another form of DAF float treatment (anaerobic digestion) can yield methane, a combustible gas which can help offset the energy costs of pollution control operations.(80) The Coors brewery uses chemical treatment and DAF to thicken sludge from a secondary wastewater treatment plant. An approved water treatment polymer is added to assist in the flotation process. The concentrated sludge from this operation is then dewatered through evaporation to produce a material which will be marketed as animal feed, but only in the State of Colorado because FDA has not approved it for use in interstate commerce.

As byproduct development becomes more attractive, consideration should be given to the use of chitosan as a coagulation aid during DAF treatment. Chitosan has been effectively used as a coagulant for wastewaters generated by food industries such as vegetable processing, fruit cake production, egg breaking, meat packing, poultry processing and seafood processing (the latter at an Atlantic Coast shrimp processing and breading operation).(15, 16, 18, 20, 22) This natural polymer has been found to be at least as effective as, if not superior to, synthetic polymers. Because chitosan is a natural compound, sludge byproducts such as animal feeds are more plausible. Feeding studies involving rats and chitosan-coagulated byproducts have indicated no significant physiological effects. However, the Food and Drug Administration (FDA) has not approved chitosan as an animal feed ingredient as of this time.

Foreign seafood processors have made more progress than domestic operations in terms of DAF float handling and byproduct development.(212, 224, 234, 252) In the United States, only limited research performed principally by the tuna industry has been done in these areas. The FDA must approve any potential marketable use of the DAF float due to the presence of coagulants; however, the seafood industry in the United States has not pursued such approval for any type of byproduct. Consequently, the domestic processors which employ DAF treatment generally dispose of the float in landfills.

5. DAF Float Disposal. Land disposal has been the principal form of sludge disposal in the United States.(126) Recently, the application of sludges on agricultural land has gained importance as opposed to burying the material in landfills.

All types of sludge contain liquid and solid components which will dictate the physical handling procedures and environmental concerns of land disposal. For dewatered DAF float from seafood processors, application methods include land spreading; for liquid float, application methods include spraying onto the ground or injection beneath the soil surface.

Disposal practices which rely on land application must take into account the ability of the soil/plant system to assimilate the materials applied to the land. The liquid portion is dissipated through percolation, evaporation and transpiration. Suspended matter is removed by soil particles which act as a filter, and by naturally-occurring bacteria which can decompose simple organic compounds. Nutrients such as nitrogen and phosphorus may be removed by the cover crop or fixed within the soil structure.

When using land application as a disposal method, the following characteristics of DAF sludge from seafood processing operations must be considered: a.) nitrogen content; b.) oil and grease content; c.) sodium concentration; d.) salinity; and e.) odor potential.

a. Nitrogen Content. A critical factor in applying DAF float to the land is the ability of the soil/plant system to assimilate nitrogen. Crops will use nitrogen for growth; however, some species will use more than others.

The soil structure must be permeable, allowing the nitrogen to reach the plant roots. But if the soil is too permeable the nitrogen will rapidly pass beyond the root system, out of reach for plant uptake. Nitrogen should not be allowed to contaminate the groundwater, thus soils with high water tables are inappropriate. Assuming appropriate soils are available, sludge application rates should be controlled so that the nitrogen applied is not in excess of the sytem's ability to assimilate it.

b. Oil and Grease. If oil and grease are allowed to concentrate on the soil surface or within a small subsurface area, then the soil can become impervious. Oil and grease constituents of DAF float, therefore, require controlled application and careful incorporation into the soil. The hydrocarbon molecules in oil and grease will be decomposed by common soil bacteria if the rate of application is controlled.

c. Sodium Concentration. Because excessive sodium concentrations can create soil impermeability problems, the rate of sludge application must be within the capacity of the soil to handle sodium. Different soils can accommodate different levels of sodium.

d. Salinity. Excessive salt buildup can sterilize soil and inhibit microbial activity which is necessary for the decomposition of waste material. In addition, crops have limited tolerances to salt accumulation, which is a consideration with the wastes incurred by seafood processors.

e. Odor Potential. The decomposition of waste organic material can create odor and insect problems if a land application site is poorly operated. The potential for such problems is minimized by quickly incorporating the deposited material into the soil.

6. Summary. As seafood processors proceed to meet their pollution control responsiblities, the DAF treatment scheme will begin to be utilized by an increasing number of plants. Consequently, an increase in the volume of float generated will result. Although only a limited number of processors currently use DAF technology, this technology has been identified herein as being appropriate for much of the industry. DAF float (i.e., the solids, oil and grease) removed from processing effluents will be utilized, or it will require disposal.

DAF float generated by the seafood industry in the United States is currently being transported to landfills for disposal. However, as landfill operations are subjected to more rigorous evaluation, an increasing emphasis will be placed on DAF float utilization. Because the residuals from seafood wastewaters are high in nutrients and protein content, potential uses for these materials include animal feed supplements and fertilizers for agricultural activities.

Ultimately, the generation of float will depend on the number of seafood processors adopting this technology for water pollution control. What these processors do with the float will be more an issue of economics: simple disposal will continue to be favored by the processors as long as sites are available and the costs for disposal are less than those for byproduct manufacturing and marketing.

E. Waste Activated Sludge

The previous discussion of byproduct manufacturing from seafood wastes has included gross solids, screened solids and DAF sludge. The fourth and final category of solids which may be incurred by seafood processors adopting wastewater treatment is waste activated sludge. Biological treatment systems which generate this material rely on the maintenance of a large mass of microorganisms which are capable of decomposing organic wastes. The activated sludge system is widely used for treating municipal and industrial wastewaters, but has only limited applicability to the seafood industry.

High capital and operating costs, large land area requirements and the need for steady operating conditions are among the reasons the seafood industry has not adopted biological systems for treating processing wastes. Such systems can achieve waste reductions that are beyond those obtained by screening and DAF technology. Most processors are located in developed coastal areas where land is simply not available for construction of large treatment systems. In addition, the fluctuations in processing schedules would generally inhibit the effectiveness of most high-rate systems. Lagoons, which represent low activity treatment, require even greater land areas. For these reasons, most of the available information about the character of waste activated sludge with the biological treatment of fish processing wastes has been gained through research activities or inferred from information available for treating other types of wastewater.

Waste activated sludge from municipal and industrial treatment systems has been finding increased use as a soil amendment, in some cases supplying nutrients for crop-growing. Such crops are not be used for human consumption because a considerable amount of research is required to establish its safety. Concern remains for crop retention of toxic chemicals which are generally present in these sludges.

Growing awareness of the nutrient value of sludge has led to increasing demand for this material by farmers and homeowners interested in enriching their field crops, gardens or lawns. This demand reflects the fact that, in some cases, the sludge is given away at no cost; normal market conditions have not yet been established. Some plants charge a fee for delivering the material; however, this fee is generally intended merely to offset any special handling and transport costs for the delivery service. The value of the product itself is not usually considered. Sludge utilization in such cases is viewed simply as a disposal alternative.

Some efforts have been made to create byproducts from waste activated sludge, such as a nutrient-balanced dry fertilizer product. There has also been increasing interest in the protein content of the sludge, which can be processed to a single-cell protein (SCP) product and used as an animal feed.

Waste activated sludge is not apt to be a common concern for seafood processors. Processing facilities which employ biological treatment will probably follow the course established by municipal and other industrial operations which have produced and will continue to produce the greatest volumes of biological sludges.

F. Summary - Byproduct Manufacturing

This section has introduced a variety of concepts and applications for byproduct recovery from residuals generated by the seafood industry. Byproduct manufacturing offers two principal advantages to the industry: 1) the recovery of a potential revenue-generating product from material that was once discarded; and 2) the reduction of waste loads discharged to effluent streams with a corresponding reduction in pollution control costs. Two byproducts - meal and chitosan - appear to have the greatest potential for meeting the long-term needs of the seafood industry. These byproducts are discussed in more depth in the following sections of this chapter.

IV. MEAL PRODUCTION FROM SEAFOOD WASTES

A. Background

In general, there is a worldwide shortage of protein. While this may not seem evident in the United States, there are other countries and continents which have significant protein deficiencies. Protein prices in the United States are low compared to those in other parts of the world; European prices, for example, are twice those established in the United States. Worldwide shortages are aggravated by worldwide population growth.

The sea offers an abundance of protein, but only a portion of that which is harvested gets utilized. To approach total utilization, fish processors must rely on the production of secondary seafood commodities and byproducts. Otherwise, much of the protein brought to shore is returned to the environment as waste material. Fish meal is a widely-accepted proteinaceous byproduct which can substantially increase the total yield of protein currently achieved by the fish processing industry.

Within the contiguous United States, many of the larger tuna canneries already operate on-site meal production plants. The processing of tuna scraps is supplemented by anchovy reduction at specific plants during part of the year. However, the seafood industry as a whole has not installed this type of on-site byproduct equipment, largely because of intermittent production schedules and the poor profitability experienced by some meal producers. A number of the processors send their waste material to general rendering facilities which produce meal and other products (such as tallow and oil) from proteinaceous wastes received from various sources. It would appear that the concept of centralized fish meal facilities, cooperatively handling strictly fish wastes from a number of local processors, may be economically more attractive than operation of on-site equipment at individual plants.

Small fish meal plants able to process 250 to 1,000 kilograms of raw material per hour are manufactured and sold as package units; however, none of these have been identified operating within the United States seafood processing industry. The relative cost of operating a small-scale meal plant is high compared to larger operations, largely due to the economy of scale. Even the larger plants located in Alaska have generally not been operated at an acceptable profit level; some actually lose money. Recognizing this, fish processors have come to regard the operation of meal plants as an alternative means of waste disposal, rather than a business venture. To these processors, meal production may represent a lower-cost or less involved waste disposal method than barging or landfilling. The possibility exists for competing processors to cooperatively subsidize meal plants in the mutual interest of keeping waste disposal costs to a minimum.

Obviously, meal production would be a preferable disposal method in terms of total resource utilization. The world market value for protein tends to fluctuate, but has generally been increasing. As this market improves, the economic advantages of meal production will increase. Concurrently, the cost of other forms of disposal may rise, creating a greater incentive for processors to choose meal production instead of ocean disposal or land disposal of their wastes. Since the operation of modern fish meal facilities is fairly energy intensive, future costs to meet energy requirements will also play a significant role in the economics of meal production.

B. Alaskan Meal Production

In Alaska, three fish meal facilities are currently operating. Two typical fish meal installations are operated by processing plants in Petersburg and Seward. Both include an evaporator for stickwater, the waste stream containing soluble protein which is extracted after the cooking process. Neither installation has been operating at full capacity on an annual basis because of raw material supply limitations. The reluctance of other processors in the respective areas to separate gross and screenable solids have contributed to this situation. The third (and largest) meal plant, Bio-Dry Incorporated, is located in Kodiak, where it receives wastes from about 15 area processors. Meal commodities are produced essentially year-round, while fish oil is recovered during the processing of finfish wastes. Stickwater is discharged to the harbor without treatment.

The two smaller operations (at Petersburg and Seward) accept raw waste materials transported by local processors, paying nothing for the wastes and charging nothing for their acceptance. The Kodiak plant charges a fee for going out and collecting raw wastes from local processors, much as a municipal refuse collector might do. Processors who instead choose to transport their wastes to the Bio-Dry plant receive a credit (to apply against processing fees). Thus, the only exchange of money is from the processors to the meal plant; in effect, a service fee for waste disposal.

Because meal production is one of the few alternatives for disposal/utilization of Alaskan seafood processing wastes, special care has been taken to identify key seafood processing centers for further evaluations regarding the feasibility of operating meal plants in these areas. The rationale for identifying selected areas will be presented to establish the basis of economic evaluations to be conducted by another contractor, as part of the Section 74 study.

Previous assessments of the seafood industry, have shown that, although conditions vary from place to place, the Alaskan industry as a whole differs significantly from that established in the contiguous United States. Some of the factors uniquely influencing the treatment and disposal of seafood wastes include labor availability, weather, geography, geologic and soil conditions, and relatively high costs for construction and transportation activities.

Earlier assessments regarding waste control within the seafood processing industry differentiated between remote and non-remote areas of Alaska, identifying non-remote areas as those having significant population density or processing activity. Designated non-remote areas are Anchorage, Cordova, Juneau, Ketchikan, Kodiak and Petersburg. It was determined that fish processors in these areas are capable of achieving greater reductions in waste discharges than plants in remote locations. Not all plants in designated non-remote areas have installed the appropriate equipment (screens) to realize achievable pollutant reductions.

In addition to the designated non-remote areas, there are three remote locations which support substantial fish processing activity: Naknek-South Naknek (Bristol Bay); Dutch Harbor; and the Kenai Peninsula, which includes Kenai, Soldotna, Ninilchik, Homer and Seward. Because these have been designated as remote areas, fish processors simply grind and discharge their wastes to local receiving waters.

Profiles of the nine major processing areas in Alaska are presented below.

1. Anchorage. Because it is Alaska's largest population center, Anchorage has been designated as a non-remote area. However, the city has relatively little seafood processing activity, limited to one large cannery and a cold storage plant, mostly handling salmon. Wastes generated by the cannery represent a much greater volume than those produced by cold storage plant. The cannery wastes are ground and discharged to a small stream called Ship's Creek. Waste materials from the cold storage facility are transported either to the city landfill or the Seward reduction facility.

Because Anchorage is not a major processing area, it is not reasonable to suggest a centralized fish meal operation there. There is an existing reduction plant (150 metric tons per day capacity) in the Kenai Peninsula at Seward, over 100 miles from Anchorage. Since the reduction facility is operating below capacity, transporting the wastes to Seward represents a viable alternative. Or, the Anchorage processor could install its own, on-site byproduct manufacturing equipment. If screens were to be installed at the Anchorage processing plants, the accumulated wastes (gross and screened solids) would require some form of byproduct manufacturing or disposal. A designated ocean dumping site is within 5 miles of the city.

2. Cordova. There are four seafood processing plants in Cordova and its immediate vicinity. The principal commodities include canned and fresh/frozen salmon, Tanner and Dungeness crab, frozen herring in the round, and herring roe. Cordova is currently designated as a non-remote area. It is surrounded by mountains which make the city rather inaccessible to other population centers by ground transportation. However, the city is serviced by the state of Alaska marine highway (ferry system) and commercial airlines.

Because more than three processors are located in Cordova and it is a non-remote area (thus subject to more rigorous waste controls), Cordova is one of the areas which should be evaluated for centralized fish meal production. The separation of finfish solids and shellfish wastes should be included in the analytical process due to the different values associated with the respective meal products.

3. Juneau. Juneau is Alaska's state capital and one of its larger cities; therefore, it is included in the list of non-remote areas. Like Anchorage, Juneau does not support an extensive fish processing industry. Two major processing plants are located in the Juneau area; principal commodities are canned and fresh/frozen salmon, and halibut. Because the processing schedule is normally limited to the summer months, barging of wastes to a designated dumping site during this season would not be a problem. Juneau is served by a secondary wastewater treatment plant which would appear capable of handling wastewater from seafood processors. An easily accessible private landfill site is available within 5 miles of the local population center.

The number of processing plants operating in the Juneau area limits the practicality a cooperative waste reduction facility there. Byproducts could be manufactured individually by the two processors; a foreign manufacturer can provide meal plants ranging from 250 to 1,000 kilograms per hour for this type of application.

4. Ketchikan. With an estimated 1976 population of over 10,000, Ketchikan is classified as a non-remote area. Three major seafood processors operate within the city limits and a fourth is located about 3 miles from the population center. Employment statistics show a seasonal fluctuation that coincides with the processing season. The main products for this area are canned and fresh/frozen salmon, halibut, herring and bottomfish.

Ketchikan's location and relatively mild weather allow seafood processing wastes to be barged for deep sea disposal essentially year-round. Local geographic conditions limit the potential for land disposal of wastes. Because the city has no municipal wastewater treatment system, this waste disposal alternative is also unavailable to local processors. Thus, byproduct manufacturing represents one of the few remaining alternatives to ocean disposal. The feasibility of a centralized fish meal production facility should be given detailed consideration for the Ketchikan area.

5. Kodiak. Fourteen seafood processors were operating within the city of Kodiak in 1977, and a fifteenth plant is located just outside city limits. Thus Kodiak supports an extensive seafood industry; principal commodities include canned and fresh/frozen salmon, halibut, King and Tanner crab, shrimp and herring. The city's population density further justifies its designation as a non-remote area.

Fish processing operations continue throughout the year at Kodiak. And, as noted earlier, area processors can have their wastes picked up by or delivered to Bio-Dry, Inc., a local 200-ton-per-day meal plant. This plant, however, does not evaporate stickwater to enhance the meal quality. In addition, the variety of species processed in the area (i.e., both finfish and shellfish) hinders the consistency and quality of the final meal product. Nonetheless, local processors have been sending their wastes to the meal plant since 1973.

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The Kodiak processor's have established experience utilizing a centralized meal plant as a waste disposal option. The operation of the existing facility, as well as its modification to improve product quality, should receive detailed analysis.

6. Petersburg. The city of Petersburg is designated as a non-remote area. Four seafood processing facilities are operating or have operated in the city, producing fresh/frozen and canned salmon, halibut, herring fillets, Tanner and King crab, bottomfish and shrimp. Herring is also frozen whole and stripped for roe.

In 1974, one processor initiated operation of a fish meal plant with a capacity of 100 metric tons per day. The reduction plant has received wastes from local processors, as well as from seafood plants operating in other areas. Separation of finfish and shellfish waste is an integral part of the operation. The barging of wastes from the non-local processors to the reduction plant has stopped because of the cost incurred in transport. The Petersburg reduction facility does not operate year-round and has never operated at full design capacity.

7. Naknek-South Naknek. As many as seven salmon processing plants have operated along the Naknek river, making this a significant remote area in terms of fish processing activity. However, the salmon season here averages only 10 processing days occuring during a 3-week period. This extremely short duration of waste generation is not conducive to supporting a conventional fish meal plant.

8. Dutch Harbor. In recent years, the Dutch Harbor area has grown to be the second largest seafood processing port in the world. The major commodities are King and Tanner crab, and shrimp. A very small volume of salmon is processed in this area. In view of the volume and frequency of waste generation, this processing center may provide significant raw material for chitin/chitosan production at a future time. The low value of shellfish meal and the logistics associated with the Dutch Harbor area are obstacles to the feasibility of operating a centralized fish meal plant.

9. Kenai Peninsula. There are a number of seafood processors situated in a relatively small geographical area known as the Kenai Peninsula. This land mass is adjacent to Anchorage, extending south into the Gulf of Alaska. Processors are located around the perimeter of the peninsula in such municipalities as Kenai, Soldotna, Ninilchik, Homer and Seward. Principal seafood commodities include canned and fresh/frozen salmon, halibut, King and Tanner crab, and herring.

The largest and most diversified processor on the Kenai Peninsula is located at Seward, where operations include a fish meal plant which is capable of processing 150 metric tons of raw materials per day. The Seward plant handles wastes from its own processing activities, along with a small volume from another local processor. However, the plant has not operated anywhere near its capacity. Therefore, considerations should be given to accepting solids

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generated by other processors located on the peninsula and Anchorage plants during economic evaluations.

V. CHITIN/CHITOSAN PRODUCTION FROM SHRIMP AND CRAB WASTES

Meal commodities manufactured from shellfish (shrimp and crab) wastes contain less protein and have a poorer market value than those manufactured from finfish wastes. Because of this, attention must be given to alternative methods of utilizing or disposing of shellfish wastes. A variety of secondary products and byproducts have already been described in this report. Of these alternatives, the manufacturing of chitin and its derivative, chitosan, appears to offer a unique opportunity for waste utilization which should continue to be explored.

A. Description of Chitin/Chitosan Production Process

As shown in Figure 11, chitin production requires deproteination and demineralization of shell material. Caustic and hydrochloric acid extraction steps yield the residual polysaccaride, chitin, which is then washed, dried and ground into a white powdery substance. Chitin can then be converted into chitosan through a deacetylation (hot caustic) process as shown in Figure 12. The entire process is quite sophisticated, and requires extensive quality control measures, but it produces five marketable products: 1.) chitin; 2.) chitosan; 3.) protein; 4.) calcium chloride; and 5.) sodium acetate. In lieu of sodium acetate separation, a caustic recovery process can be incorporated to reduce chemical costs.

B. Properties and Applications of Chitin/Chitosan

Chitin is an abundant natural carbohydrate polymer, found not only in shells but also in insect exoskeletons and, to a lesser extent, in fungi and other plants and animals. It is similar to other natural polysaccarides, such as cellulose, pectin, starch, and carrageenan. However, most of these polysaccarides are chemically neutral or, in some cases, acidic. Chitin differs from the rest because it has the characteristics of a base (cationic), rather than an acid.

Because they are cationic and possess a high electrical charge density, chitin and its derivative, chitosan, exhibit unique properties in combination with other substances. For example, its high electrical charge density and potential binding capacity give chitosan the ability to form an ion-exchange resin, capable of recovering toxic metallic ions from waste streams. It can also help coagulate materials from various types of wastewater, yielding a natural coagulated material which may be recycled or utilized more readily than the residuals from other coagulation processes. For example the use of chitosan to remove suspended solids from food processing wastewaters results in coagulated solids that can potentially be used as an animal feed supplement. Chitosan can be made into specialty films such as food wraps and ion-selective membranes for water and wastewater treatment systems. It produces a strong bind with negatively-charged polymeric products, giving it applications in the paper-making, textile-dyeing and adhesives industries (to name a few). It promotes the healing of wounds in humans, and could also be used as a natural

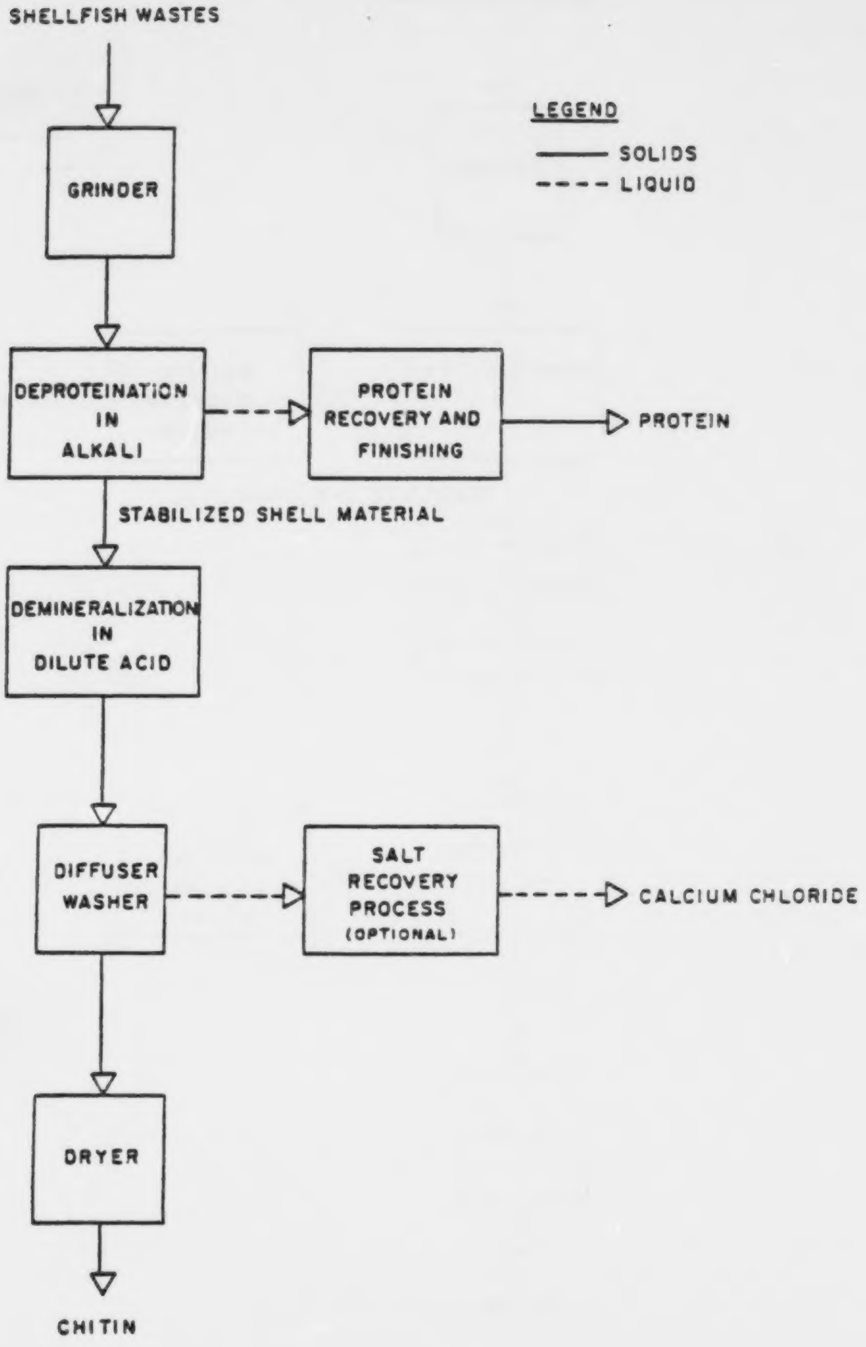
SHELLFISH WASTES
LEGEND
SOLIDS
LIQUID
GRINDER
DEPROTEINATION IN ALKALI
PROTEIN RECOVERY AND FINISHING
PROTEIN
STABILIZED SHELL MATERIAL
DEMINERALIZATION IN DILUTE ACID
DIFFUSER WASHER
SALT RECOVERY PROCESS (OPTIONAL)
CALCIUM CHLORIDE
DRYER
CHITIN

Figure 11. Process schematic for chitin production from shellfish wastes.

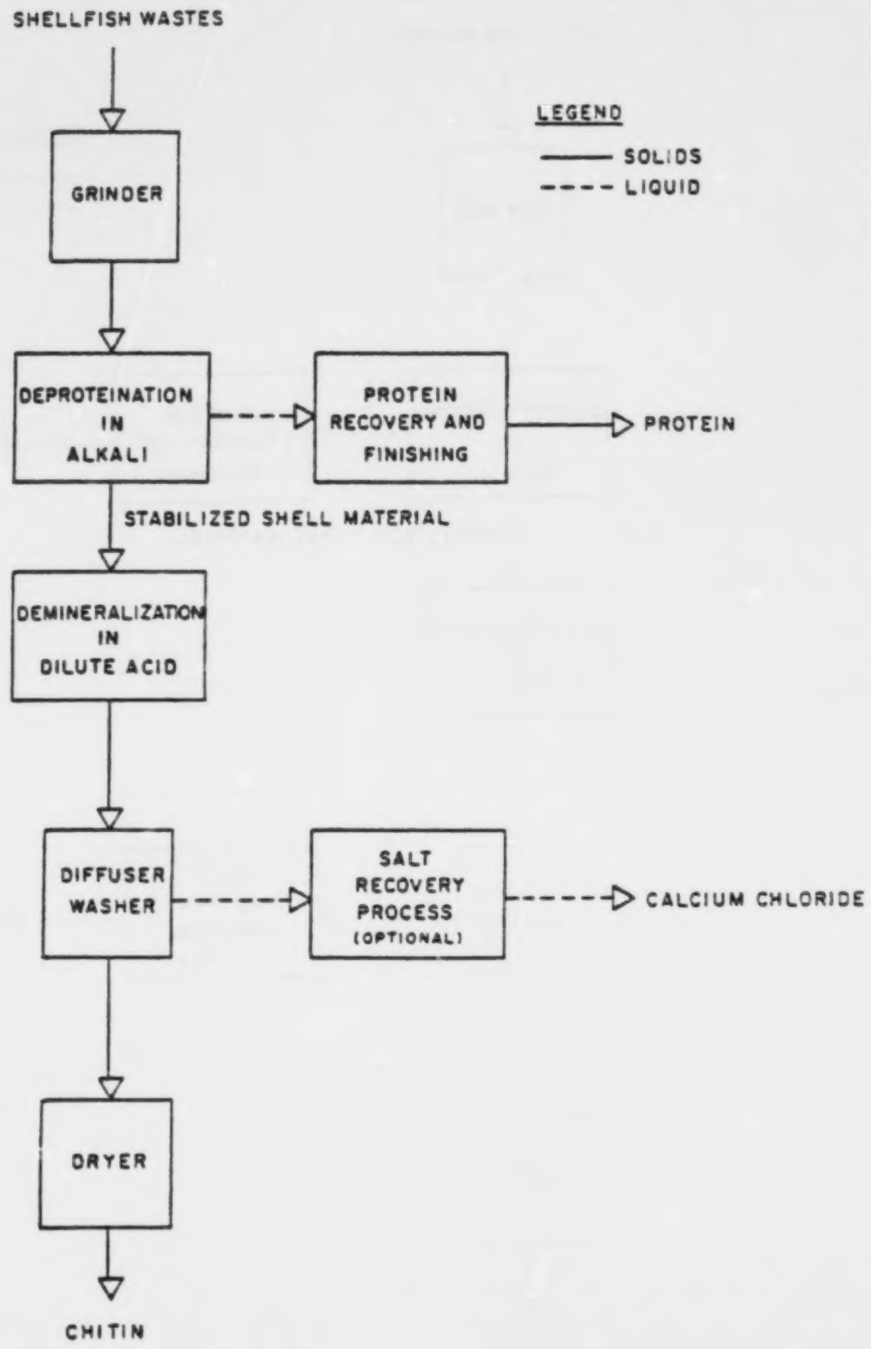
SHELLFISH WASTES
LEGEND
SOLIDS
LIQUID
GRINDER
DEPROTEINATION IN ALKALI
PROTEIN RECOVERY AND FINISHING
PROTEIN
STABILIZED SHELL MATERIAL
DEMINERALIZATION IN DILUTE ACID
DIFFUSER WASHER
SALT RECOVERY PROCESS (OPTIONAL)
CALCIUM CHLORIDE
DRYER
CHITIN

Figure 12. Process schematic for chitosan production from chitin.

suture material. Derivatives seem to have application in the selective aggregation of cancer cells. Table 8 lists 76 applications which were identified by a Brownsville, Tecas, producer who has since discontinued operation.(111)

C. Current Status of Chitin/Chitosan Production

Despite all these potential applications, there is presently only one manufacturer (small scale) of chitosan in the United States. Previously, pilot-scale facilities have produced chitosan and then discontinued their operations because of economic considerations. None of these have practiced the recovery of byproducts (calcium chloride and sodium acetate). Other organizations have merely conducted research or contemplated full-scale production of chitin/chitosan from selected shellfish wastes. Most of the world's supply of chitosan is produced by a single manufacturer located in Japan.

The single United States manufacturer of chitosan is located in Seattle, Washington. Chitosan is manufactured on a pilot scale, having no large, readily-identified market for the material. An earlier chitin/chitosan production plant with a rated capacity of about 150,000 pounds per year, was operated in the Brownsville, Texas, only for a limited time due to economic considerations. Velsicol Chemical Corporation of Chicago is currently seeking funding for a pilot scale production plant which would be able to accommodate the variable nature of the raw material, in this case crab shells, and evaluate byproduct technology. The proposed pilot facility requires an initial capital investment of $2 to $3 million and would be located in the Hampton/Newport News, Virginia area or on the Delmarva peninsula of Maryland and Virginia. It would require about 5 million pounds of blue crab shell annually, to support production of 10 tons of chitin per month. Based on the findings of pilot plant investigations over a two-year period, full-scale facility, capable of producing 3 million pounds of chitin/ chitosan annually, could be more extensively evaluated. This facility would be supported by an annual crab waste generation volume of 60 million pounds from processors in Virginia, Maryland, North Carolina and the northern part of South Carolina.

Among the factors limiting chitin/chitosan production are raw material supplies, raw materials transport, production complexities, and market demand for the finished product. Each of these factors are discussed individually below.

1. Raw Materials. Chitosan production facilities in the United States, such as the one which once operated in Brownsville, Texas, have had difficulty receiving a steady, reliable supply of low-cost raw material. Part of the problem is that processors can still find other ways to dispose of their wastes. However, landfills are becoming more reluctant to accept unstabilized materials, such as seafood wastes, and meal plants are not realizing a profit from handling shellfish wastes. Many local processors are thus finding themselves faced with alternatives, at a time when regulatory pressures are building for more effective ways of dealing with seafood industry wastes.

TABLE 8

IDENTIFIED CHITIN/CHITOSAN APPLICATIONS (111)

1. Superior adhesive for plywood manufacture. (The bond is stronger than the wood even after soaking in water.)
2. Superior adhesive for laminating paper (water resistant).
3. Superior adhesive for laminating wood blocks (water resistant).
4. Superior adhesive for joining paper to regenerated cellulose.
5. Superior adhesive for joining paper to wood (water resistant).
6. Superior adhesive for joining paper to cloth (water resistant).
7. Superior adhesive for joining paper to leather (water resistant).
8. Superior adhesive for joining paper to glass (water resistant).
9. Superior adhesive for joining wood to cork (water resistant).
10. Superior adhesive for joining wood to leather (water resistant).
11. Superior adhesive for joining wood to glass (water resistant).
12. Superior adhesive for joining wood to rubber (water resistant).
13. Superior adhesive for joining wood to rayon (water resistant).
14. Superior adhesive for joining wood to canvas (water resistant).
15. Superior adhesive for joining leather to leather (water resistant).
16. Superior adhesive for joining leather to cork (water resistant).
17. Superior adhesive for joining leather to regenerated cellulose (water resistant).
18. Superior adhesive for joining cork to rayon (water resistant).
19. Superior adhesive for joining cork to canvas (water resistant).
20. Superior adhesive for joining rayon to rubber (water resistant).
21. Superior adhesive for joining rayon to cloth (water resistant).
22. Superior adhesive for joining regenerated cellulose films to other cellulose films (water resistant).
23. Superior prime coating base for painting with specialty paints.
24. Furniture glue (water resistant).
25. Manufacture of wood veneer paper (water resistant).
26. Laminating safety glass.
27. Imparting increased wet and dry strength in paper manufacturing.
28. Imparting water resistance to finished paper.
29. As surface sizing on paper to impart both oil and water resistant properties.
30. Increasing water resistance of cellophane.
31. As an emulsifying agent and thickener in proprietary sizing emulsions.
32. As a thickener in nonemulsion formulations.
33. As a semi-permanent finish on wool to improve laundering properties and aid in retaining shape and greatly reducing shrinkage.
34. As an antistatic coating for synthetic fibers.
35. As a contributer of semi-permanent fullness and stiffness to cotton fabrics. (Also imparts some water resistance.)
36. Improves acidic foot ointments.
37. Improves antacid tablets.
38. Improves contraceptive jellies.
39. Improves antiperspirants.
40. Improves dyeing characteristics of cellulose fibers and films.

TABLE 8 (Continued)

41. As additive to infant food (including livestock) to enhance growth of the essential Lactobacillus-Bifidus, thus enhances weaning earlier with less danger of complications.
42. As an additive to tetracycline promoting rapid adsorption of the antibiotic by the blood stream and maintaining the tetracycline at a high level.
43. Has similar function to above with other antibiotics.
44. As plastics adhesive.
45. As lubricant and sizing agent in the manufacture of fiberglass reduces abrasion and breakage of fibers during handling and weaving.
46. Increases color capability of fiberglass.
47. Specialty adhesive for plastic to fiberglass laminates.
48. In removing mercury from industrial effluents.
49. In recovering mercury pollutants to useful compounds.
50. In coagulating oily industrial wastes thus permitting recovery and preventing pollution.
51. In wound dressings.
52. In biomedical application such as an artificial skin.
53. As special edible food wrappers.
54. In reverse osmosis units.
55. For recovering trace metals from waste, sea and source waters.
56. For definitive water pollution surveying.
57. For imparting radically increased strength to synthetic fibers used in various fabrics.
58. In domestic sewage treatment plants in remote locations such as base camps for Alaska pipeline, and where conditions of terrain make other processes impracticable.
59. As a clarifier in breweries.
60. For improving electrical conductivity of special papers, such as used in xerox and other photocopying processes.
61. In brewery waste treatment for recovering animal feed-stuffs.
62. For recovery and re-use of undgested proteins from animal wastes.
63. For recovery and re-use of dissolved protein resulting from shellfish and finfish processing.
64. For recovery and re-use of products from cheese whey in big diaries.
65. As an anti-coagulant intravenous substitute for Heparin use (primarily for preventing blood clots).
66. For adsorbing D.D.T. and other similar insecticides.
67. As a surgical suture with properties that accelerate wound-healing.
68. For silver recovery in various processes.
69. For recovery of mineral resources of the sea.
70. As an oil-drlling mud additive.
71. For treatment of nuclear power plant wastes.
72. For very rapid determination of nuclear power plant pollution resulting from accident.
73. As a substrate for a microbial fermentation to produce a new enzyme "Chitosanase". Enzyme is used to control infection in human burns. (WSG)
74. For sensitizing the photo-oxidative destruction of waste organic materials, such as phenols in industrial effluents. (WSG)
75. For coating and encapsulating particles. (WSG)
76. As a substrate for controlled release or herbicides (WSG)

Considering the current shellfish harvests a substantial chitosan industry could be established in the United States. Although they are seasonal, shrimp and crab waste supplies appear plentiful in the Pacific Northwest, Alaska and the Chesapeake Bay area. The Dutch Harbor area of Alaska generates a huge amount of shellfish wastes. However, the remoteness of this area prohibits serious consideration regarding local chitosan production. Local processors have been approached by the Japanese, who are interested in buying stabilized shells from the Dutch Harbor area. Stabilization can be achieved through deproteinization of the waste material (first chemical process step in chitin production) with a weak alkalai solution. Not only would shell stabilization occur, but high grade proteinacous material could be recovered (90 percent protein). The sale of the protein would significantly improve the economics of operating such a facility. The U.S. Department of Transportation (DOT) has published regulations for the shipboard transport of the alkali chemical required for this process as well as those pertaining to hydrochloric acid required for demineralization to produce chitin. In view of the quality control which must be excercised for chitin production, stabilization appears to be the limit for shellfish wastes processing in Alaskan areas.

The availability of shellfish wastes within a given region would have to be accompanied by a willingness by local processors to cooperate in supplying a chitin/chitosan manufacturing plant. Market values for chitosan vary depending on the specific application. But the major volume markets (such as wastewater coagulation or papermaking) would require a relatively low selling price for chitosan. Low chitosan prices can only be achieved by large-scale production plants receiving consistent supplies of raw material at minimal cost. Transportation cannot represent a large portion of the costs associated with operating a chitin/chitosan plant.

2. Cost. To be economically feasible, chitosan production would have to be large in scale and consistent in quality. Regional processing centers are thus attractive, receiving wastes from selected areawide processors. Velsicol estimates that the production costs associated with a full-scale chitosan plant would be approximately $2.00 per pound of chitosan; whereas their pilot facility which incorporates added versatility would produce chitosan for about three to four times that amount. Investigations conducted by a Sea Grant Institution supports the $2.00 per pound production cost.(64) The Japanese company which currently produces most of the world's chitosan sold the product for about $3.00 per pound in 1978, plus transportation costs.

3. Markets. Despite all the potential uses of chitosan, a firm market for this material has not yet been established. The technology exists for its production, but additional research is needed to ensure adequate product performance in many of its applications. Development of a strong market would probably result from two achievements: 1) a steady output of consistently high quality chitosan; and 2) a full-fledged marketing (sales) effort.

The reluctance of private industry to enter the area of chitin/chitosan production reflects the major capital investment required to construct a manufacturing plant of large enough capacity to allow a competitive price structure. Prices are a reflection of demand, which many feel is not yet great enough to justify capital expansion. One of the uses of chitosan is in the coagulation of wastewater. If the Food and Drug Administration were to approve chitosan as an animal food additive, then it would create immediate demand for chitosan as a coagulant for proteinaceous food processing wastewaters. Sludge from the treatment process could then be used as an animal feed.

The Sea Grant Program at the Massachusetts Institute of Technology recently reported that chitosan production would be commercially feasible at a production rate of between 1 and 4 million pounds per year at a selling price of $1.00 to $2.50 per pound.(64) The recommended scheme requires that participating local shellfish processors separate their wastes into two parts: 1) a mechanically separated protein; and 2) shell waste residual. The shell waste residual would be sold to a regional or national-level producer of chitin derivatives. Several other researchers and industry representatives have expressed skepticism with regard to the economic feasibility of any such plan.

D. Outlook

Skepticism aside, chitin/chitosan production appears to offer an alternative to meal production or other forms of shrimp and crab waste disposal. The potential uses or markets for chitosan have only recently been seriously researched, but already indicate the broad range of applications for the material. In the long run, chitin/chitosan production will have to be considered seriously, not only for its own sake, but also for the sake of resource utilization and hence of environmental protection.

The largest and most immediate use of chitosan appears to be for wastewater coagulation, particularly in cases where the use of a natural polymer might enhance the market value of the coagulated sludge (e.g., as an animal feed). Beyond this, it would be difficult to speculate which application will emerge as the best potential market for chitosan, or at what price. Nor can it be predicted when or if this market will develop.

In the immediate future, it appears that chitosan production in the United States will need to continue at pilot and demonstration levels, awaiting the establishment of firm market, predictable price structure, and consistent quality product. As these develop, chitin/chitosan production may indeed emerge as a long-term solution to the problem of shellfish waste disposal for certain areas of the country. Such areas would have to contain enough shrimp and/or crab processors within an acceptable distance to provide a consistent supply of raw material in support of large-scale chitosan production. Not all processors will fit into such a scheme.

VI. ULTIMATE DISPOSAL OF SEAFOOD WASTES

In selecting a waste disposal alternative, a seafood processor should first consider the manufacture of secondary products or byproducts from this proteinaceous material. If this appears unfeasible, then land application should be considered, again attempting to take advantage of valuable materials in the seafood wastes for agricultural purposes. If none of the above courses of action can be implemented, then the processor must consider the ultimate disposal of processing wastes by some other means. The two principal alternatives for final disposal are barging (ocean disposal) and landfilling.

A. Barging

Alaskan seafood processors have the option of barging their waste materials to designated deep sea disposal sites which are generally within 5 miles of shore. Barges are generally operated by individual processors; however, cooperative efforts are also a realistic option. In the contiguous United States, most processors have other disposal alternatives available, such as landfilling and centralized byproduct manufacturing facilities. The United States territories of Puerto Rico and American Samoa support major tuna canneries which are accompanied by fish meal plants. At the byproduct facilities, stickwater is not evaporated to produce solubles; instead, this concentrated waste stream is either barged to sea or directed to the respective wastewater treatment system. Treatment system performance is impacted when the stickwater is received at the wastewater plant.

B. Landfilling

The landfilling (or burial) of sludges and other solid wastes has traditionally been the most common and least expensive method of disposal. However, new sites are becoming difficult to find, and there is mounting concern for the environmental impact of landfill operations. Regulations have been generated by state and federal agencies specifying the proper standards for selecting and operating a landfill site. For seafood processors in the contiguous United States, this means greater attention will have to be given to cooperative approaches and to joint municipal-industrial sludge disposal sites. Processors can participate in the operation of an existing sludge landfill or arrange for the co-disposal of residual solids at a conventional refuse landfill.

The principal material to be landfilled by the seafood processing industry is DAF sludge (float) and, to a lesser extent, waste activated sludge. But disposal of any type of sludge, including the DAF float, will become increasingly difficult as the mandated criteria of the Resource Conservation and Recovery Act (RCRA) of 1976 are implemented. RCRA prohibits future open dumps and requires upgrading or closing of existing dumps; regulates the treatment, storage, transportation and disposal of hazardous wastes to protect the land; and further requires reduction of the waste stream through increased resource recovery and waste reduction efforts. While final regulations are still being formulated, it is known that the primary focus of RCRA is on the 21 primary industries which are known to generate hazardous wastes. Since the seafood processing industry is a secondary industry, little insight can be provided regarding the impact of RCRA on float disposal.

With regulations governing landfill operations becoming more restrictive, it is important to consider dewatering the sludges to make them more amenable to burial. Dewatered float and waste activated sludges are also easier to transport to the disposal site than liquid material. Economics and imposed restrictions will dictate the need for installing dewatering equipment at the treatment plant site.

Co-disposal with other types of refuse is common for dewatered waste activated sludge. But here again, this treatment technology is not expected to find substantial use within the seafood industry. The more common sludge is expected to result from use of DAF treatment systems. The sludge, or float, from DAF units is a viscous material that can be handled as a liquid or dewatered and handled more like a solid. Evaluation of alternative dewatering systems and their related economics would need to be performed on a case-by-case basis. Dewatered and undewatered DAF sludge has been landfilled by California tuna canneries. In Puerto Rico the disposal of liquid float and dewatered float has been accomplished. Sludge concentration was found to be a necessary step for this geographical location mainly due to aesthetics and environmental considerations. In general, relatively few seafood processors have installed DAF treatment and even fewer have any experience with the dewatering and disposal of the resulting sludges.

Other food industries which employ DAF treatment units or biological treatment systems have demonstrated that their sludges can be dewatered and receive safe disposal separately in conjunction with other municipal and industrial sludges.

C. Other Disposal Methods

Several characteristics of the seafood industry have an impact on landfilling and other disposal options. A significant segment of the industry is located in Alaska, where geographic, soils and climatologic conditions eliminate landfilling as a viable disposal alternative. The prevalence of small processing plants which operate intermittently prevents consideration of high-technology, high investment waste disposal options, such as incineration or pyrolysis for most of the industry.

APPENDIX A

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APPENDIX B

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APPENDIX C

SELECTED FOREIGN ABSTRACTS

Akama, A. and T. Terai, "Treatment of Organic Wastewater." *Japan Kokai* 77 25,451 (1977);

> "Organic waste water is mixed with CaO, $Ca(OH)_2$, MgO, or $Mg(OH)_2$, and CO_2 is blown into it. Thus, 10 parts CaO was added to 100 parts waste water (COD 3,370, BOD 9,870, total N 676 ppm) from fish washing followed by CO_2 blowing and settling. The supernatant liquor contained total N 328, COD 715, and BOD 2,200 ppm". (*Chemical Abstracts*, 87, 28620x, 1977).

Emel'yanova, E.A. *et al*. "Wastewater of a Fish Meal Feed Plant as Complex Poly-disperse System," *Rybn Khoz* (USSR), 8, 73 (1976).

> "Wastewater from washing fish meal cake with hot water contains Cl,P, and N and has BOD_5 8.9 g0/1". (*Chemical Abstracts*, 86, 47004, 1977).

Emel'yanova, E.A., *et al*., "Effect of Some Electrolytes on the Coagulation of Organic Pollutants in Wastewaters." *Rybn Khoz* (USSR), 4, 76 (1977).

> "Wastewaters from the fish processing industry (fish flour factories, etc.) contain very stable colloid dispersions of fats and proteins. These dispersions are broken down by addition of electrolytes (HOAc and HCl). The dimensions of the coagulated flocs are maximum at pH 4.8 (with HOAc). The filtration time of the sediment is minimum at 0.07 ml concentrated HCl or 0.2 ml glacial HOAc/100 ml effluent. $Al(OH)_3$ did not give positive results. Polyacrylamide (1% of 0.5% solution) was tested as coagulant without noticeable effect. Colloidial 1.5% solution of SiO_2, activated with concentrated H_2SO_4 after electrolyte treatment, increased the stability of the flocs and improved the filtration rate of the sludge." (*Chemical Abstracts*, 87, 43693s, 1977).

Fujita, T. *et al*., "Studies on the Utilization of Crab Shell Waste-Chitosan as a Coagulating Agent," *Nippon Suisan Kabushiki Kaisha Chuo Kenkyusho Hokoku* (Japan), 11, 49 (1976).

> "HCHO was sprayed on powdered chitin prepared from king crab shell to obtain chitosan salt containing H_2O 10% and HCHO 18%, which was used for coagulation of clay suspension, wastewater from processing of ground fish meat, and activated sludge. In the coagulation test of clay suspension with 0.1 20 ppm chitosan, the coagulation and settling of clay particles were accelerated with increasing chitosan salt. The chitosan salt also had good coagulation effect for wastewater from ground fish meat processing and activated sludge." (*Chemical Abstracts*, 87, 172265c, 1977).

Fukuda, *et al*., "Coagulation Treatment of Waste Water from the Manufacture of Marine Products," *Mizu Shori Gijutsu* (Japan), 18, 5 (1977).

> "Polyacrylate (300 ppm) or 800 ppm $Al_2(SO_4)_3$ added to pollack meat water extraction or without pH adjustment, 83 and 66% of the proteins were precipitated, respectively. The coagulants were effective at pH 3-6. The

optimum pH to coagulate the protein was 4.5-5.0. The optimum pH decreased and the coagulation was accelerated by increasing the concentration of NaCl from 0.05 M to 0.5 M. Sucrose did not affect the coagulation." (Chemical Abstracts, 87, 106458s 1977).

Kato, T. and M. Maeda, "Electroflotation Treatment of Waste Water from the Processing of Marine Products," Mitsubishi Denki Giho (Japan), 50, 9 (1976).
"A review with 3 references on the effectiveness of electroflotation in the treatment of wastewater from fish processing and equipment installation." (Chemical Abstracts, 86, 110726z, 1977).

Kuji, Y. et al., "Treatment of Waste Water from Marine Products Processing by Electroflotation" Yosui To Huisui (Japan), 17, 10 (1975).
"Waste water from fish processing containing proteins, lipids, and extractives was treated by the electroflotation method for removal of proteins on coagulant floc at the isoelectric point. The treatment depended on type and sex of fish and aging of waste water." (Chemical Abstracts, 84, 184488d, 1976).

Kurosaki, B. "Treating Seafood Wastewaters with Mycelia" Japan Kokai 76, 20, 249 (1976).
"A seafood waste water at pH 6.0-6.5 and containing BOD 15,000-200,000 ppm is contacted in a contacting tank with mycelia containing mainly Pseudomonas for protein decomposition and yellow mycelia for hydrocarbon decomposition, cultivated in a mycelia cultivation tank, to increase the pH to 8.0-10.0 and to decrease the BOD to 5,000-30,000 ppm. An alkaline compound, e.g., $Ca(OH)_2$, is added to the mixed solution while it is being pumped to a sedimentation tank to increase the pH to 10.2-10.5. Oils, soluble proteins, and mycelia are deposited from the solutionin the sedimentation tank. A portion of the precipitate deposited is circulated to the mycelia cultivation tank for re-use. Fish oils and mineral oils are flocculated rapidly; soluble proteins are flocculated to solids. Thus, a seafood waste water containing BOD 13,000 ppm was treated by mycelia cultivation, alkali addition and H_2SO_4 neutralization. The capacity was 5-15 kg BOD/m^2 day, as compared to 0.5-1.0 kg BOD/m^2 day by using conventional aeration." (Chemical Abstracts, 84, 184641y, 1976).

Leoni, C. et al., "The Depuration of Waste Waters from Food-Preserving Factories; Effect of Sodium Chloride Concentration on the Depuration Yield of an Extended Aeration Activated Sludge Plant," Ind. Conserve (Italy), 51, 30 (1976).
"Effluents from the fish canning industries contain NaCl 11-12 g/l. The concentration should be kept under 10 g/l, and, if possible, under 5 g/l for biological purification. An artifical solution contained less than 1 g/l of peptone and fish homogenates, plus minimum concentrations of $MgSO_4$, $CaCl_2$, and K_2 HPO_4. This artificial effluent was used to prepare tests solutions containing 5-100 g NaCl/l. Analytical determinations were performed with the solutions before and after treatment in the oxidation chamber. BOD and COD values were measured. These values were obtained in the effluent before and after filtration. At 5-10 g NaCl/l

the biological activity started to decrease and sludge was difficult to separate. An excess of NaCl not only inhibits the biological action, but also corrodes." (Chemical Abstracts, 86, 19450k, 1977).

Maeda, M. et al., "Treatment of Protein-Containing Waste Waters by Electrodeposition," Japan Kokai, 75, 141, 582 (1975).

"During the treatment of protein-containing waste waters by electrodeposition, the protein-removal efficiency is markedly improved when the initial and final pH values of the waste waters are adjusted from slightly acidic to slightly alkaline in relation to the isoelectric point of the protein, respectively. The proteins are deposited on metal hydroxide flocs at the solute electrode during the electrolysis. Thus, a waste water (COD 925 ppm, containing proteins with isoelectric pH of 4.25) discharged from a fish-processing plant was electrolyzed at a initial and final pH of 3.4 and 5.2, respectively. The COD-removal efficiency was 87%; however, the efficiency was decreased to 50% if the initial and final pH was 5.2 and 6.11, respectively." (Chemical Abstracts 84, 111365b, 1976).

Maeda, M. et al., "Removal of Proteins from Waste Waters by Electrodeposition," Japan Kokai, 75, 141, 855 (1975).

"Waste waters containing proteins are treated by a double electrodeposition process, each at different pH, using solute electrodes. The 1st electrolysis is performed at an initial pH such that at the end of the electrolysis the pH is similar to that of the isoelectric point of the protein in the wastewater. The 2nd electrolysis is performed at an initial pH such that at the end of the electrolysis the pH has reached a value at which the solubility of the metal hydroxide flocs formed is minimum. Thus, a waste water (COD 1,250 ppm) discharged from a fish processing plant was 1st electrolyzed at an initial pH 5, using an Al electrode at 20 A/min/l. The pH value at the end of electrolysis was 7.57 and the COD of the resulting water was decreased to 362 ppm. The pH of the resulting water was readjusted to 6.5 and electrolyzed at the same conditions. The COD of th resulting water was 176 ppm." (Chemical Abstracts, 84, 155326u, 1976).

Maeda, M. et al., "Treatment of Waste Water from Marine Product Processing," Japan Kokai, 76, 131, 163 (1976).

"Waste water from marine product processing is treated with acidic clay or active clay, and the pollutant adsorbed clay is heated at 250 600° and reused. Thus, 2 l of a solution (COD 450 ppm) containing 2,000 ppm bonito extract was agitated with 5% granular active clay at 15° for 1 hour and filtered to decrease the COD to 130 ppm. The used active clay was heated at 250° for 30 minutes and used again. The COD decreased to 178 from 450 ppm." (Chemical Abstracts, 87, 72961h, 1977).

Maeda, M. and T. Ozawa, "Treatment of Waste Water Containing Protein," Japan Kokai, 75, 159, 150 (1975).

"Protein in waste water from fish processing was floated by foaming with air at isoelectric point. For example, waste water (isoelectric point pH

4.9) from fish descaling was bubbled at pH 4.9 with air (air/water = 50). The COD removal was 75%, compared with 34% at pH 3.3. (Chemical Abstracts, 84, 155364e, 1976).

Maeda, M., "The Treatment Waste Water by Electrical Flotation Separation," Nenrgo Oyobi Nensho, (Japan) 43, 10, 901 (1976).
"A review of the process for the treatment of waste water based on an electrode reaction. The appropriate and the practical applications are described for waste waters from the processing of marine products, recovery of vegetable proteins and paper pulp production." (Chemical Abstracts, 86, 110724x, 1977).

Matsuura, R. et al., "Electrolysis of Marine Product Processing Waste Water" Japan, Kokai, 76, 36, 764 (1976).
"The waste water from marine product processing is treated with a Ca compound and H_3PO_4 alkali metal phosphate, alkali metal acid phosphate, or Na tripolyphosphate to precipitate proteins, peptides, and amino acids with Ca phosphate and by electrolysis to reduce COD and BOD. Thus, a primary-treated waste water containing COD 150 and BOD 190 ppm was electrolyzed 2 minutes at 0.5 A/dm^2 and 10 V, $CaCl_2$ and Na_2HPO_4 [7558-79-4] were added, the water was electrolyzed 8 minutes at pH 6.5, stirred 30 minutes, and then Na polyacrylate [9003-04-7] was added. The treated water contained COD 67 and BOD 70 ppm, compared to 135 and 170 by simple electrolysis. (Chemical Abstracts, 85, 14588y, 1976).

Matsuura, R. et al., "Treatment of Waste Water Discharged from Seafood Processing" Japan, Kokai, 75, 150, 267 (1975).
"Waste waters discharged from seafood processing are first oxidized or reduced by d.c. electrolysis in the anodal or cathodal chambers of an electrolysis apparatus. The waters are then treated by electrophoresis and the proteins, peptides, and amino acids in the anodal or cathodal solutions of the electrophoresis chamber are removed by passing the solutions through an ion exchange resin column. The COD causing materials, esp. proteins, peptides, and amino acids are thus effectively removed. Thus, a waste water (COD 1000 ppm) discharged from a seafood processing plant was placed in the cathode chamber of an electrolysis apparatus separated by a polyester fiber diaphragm, and electrolyzed at an electrical potential of 5-10 V and electrical current d. of 2 A/dm^2. The COD in the resulting waters was decreased to 250 ppm. The resulting waters were placed in the cathodal chamber of an electrophoresis device and treated at electrical potential of 10 V and electrical current d. of 2 mA/cm^2. The waters from the 1st electrophoresis were again placed in the anodal chamber and treated under similar conditions. The final COD of the resulting water after the 1st and the 2nd electrophoresis was decreased to 220 and 170 ppm respectively" (Chemical Abstracts, 84, 184623u, 1976).

Matsuura, R. et al., "Treatment of Waste Water from Manufacture of Marine Products", Japan Kokai, 76, 41, 257 (1976).

"Waste water from manufacture of marine products is mixed with H_3PO_4 to adjust to pH to 2.0-6.0, at which proteins, peptides, and amino acids in the waste water exist in the zwitterion state (isoelectric point). The $Ca(OH)_2$ or $CaCl_2$ is added to the waste water and the pH is adjusted to 6.0-12.0 with H_3PO_4 to form Ca phosphates, which adsorb and precipitate the proteins, peptides, and amino acids. Thus, 1 liter of a waste water (COD 850, BOD 2,550 ppm) from marine product manufacture was mixed with H_3PO_4 to adjust its pH to 4.5, and then polyacrylic acid Na salt 40 ppm was added. After removing the resulting flocs by flotation, $Ca(OH)_2$ slurry was added and the pH was adjusted to 6.8 with H_3PO_4. The waste water was treated with polyacrylic acid Na salt (20 ppm), followed by floc removal. The treated waste water had COD 82 and BOD 90 ppm." (Chemical Abstracts, 85, 148571n, 1976).

Matsuura, R. et al., "Treatment of Waste Water from Marine Product Processing for Recycling," Japan Kokai, 76, 66, 158 (1976).

"A waste water from marine product processing is treated with H_3PO_4 and proteins, peptides, and amino acids in the wastewater are subjected to an isoelectric treatment under acidic conditions. CaO or $Ca(OH)_2$ is then added to the waste water and the pH of the waste water is adjusted to 6-12 with H_3PO_4. The proteins, peptides, and amino acids are compounded as Ca salts of H_3PO_4. The precipitates are removed, and the treated water is filtered through an adsorption bed or a filter medium and then recycled to the washing step in the marine product processing. Thus, a wastewater (5 l, COD 838 ppm) was adjusted to pH 4.5 with H_3PO_4, subjected to an isoelectric treatment, and mixed with aqueous 0.1% Na polyacrylate (200 ml). The floc was removed, the treated solution was mixed with 200 ppm $Ca(OH)_2$, and the pH was adjusted 6.8 with 20% H_2PO_4. Aqueous 0.1% Na polyacrylate (100 ml) was added and the precipitate was removed. The treated solution was passed through a bed of anthracite and sand to yield a colorless, transparent, odorless solution for recycling. The COD contents were 82 and 640 ppm after recycling 1 and 30 times, respectively" (Chemical Abstracts, 87, 140749x, 1977).

Matsuura, R. and K. Akaike, "Treatment of Waste Waters from Seafood Processing Plants by Electrolysis" Japan Kokai, 75, 120, 160 (1974).

"Seafood processing waste water is treated by a flocculation or a flocculation activated sludge process to decrease its COD to less than 610 ppm; the treated wastewater is electrolyzed altering the polarity of electrodes and simultaneous application of a.c.; and the electrolyzed wastewater is treated with activated carbon. Thus, 1 liter of an activated sludge treated wastewater (COD 600 ppm) from a fish-processing plant was electrolyzed by using Ti-cathode and Pb-anode plates at electrode distance 2.0 cm, 10-32 V, 2.5 A/dm^2, and 5 A. The polarity of the electrodes was altered every 2 minutes and simultaneously a.c. (0.5 A) was applied. The COD of electrolyzed wastewater decreased to less than 150 ppm at 0.67 A-hr/l. The electrolyzed wastewater (COD 150 ppm) was passed through a column (3 cm diameter x 1.5 m height) containing 1 liter of actvated carbon at 4 l/hour. The effluent had COD less than 49 ppm." (Chemical Abstracts, 94, 65080e, 1976).

Namisa, M. "Recovering Protein from Waste Water Containing Crude Protein," Japan Kokai, 75, 33, 142 (1975).

"Proteins were recovered from wastewater containing crude protein by adjusting pH of the waste water to 5-6, blowing air in the inlet of the pump, and adding polyacrylic salt at the outlet of the pump during the transfer of waste water containing crude protein from the adjusting tank to the stationary tank. Thus, waste water (100 kg) (dry matter = 1.43%) obtained by washing mackerel was adjusted to pH 5, and aerated in the presence of 250 ppm sodium polyacrylate [9003-04-7] (av. d.p. 50,000). The recovery of proteins was 92.31%. The BOD of the waste water after removal of the protein was 163 ppm. The protein was used as the raw material of feed." (Chemical Abstracts, 85, 10061q, 1976).

Nishide, E. "Coagulation of Fishery Waste Water with Organic Coagulants," Nihon Daogaku No Inigakubu Gakinyutsu Kenkyu Hokoku (Japan), 34, 291 (1977).

"The coagulation of fish wastewater produced in the processing of pollack meat paste, Na alginate [9005-38-3], Na (carboxymethyl) cellulose [9004-32-4] and Na polyacrylate (I) [9003-04-7] was studied by determining residual COD. I was the most effective, and the effect was enhanced by acidifying the wastewater to pH 6.0 with H_2SO_4. The protein concentration of the wastewater influenced coagulation with I". (Chemical Abstracts, 87,106395u, 1977).

Ohtake, S. "Treatment of Waste Water from Marine Paste Products Processing Plants Electrolysis-Flocculation Method," Japan Food Science, 14, 7, 58 (1975).

"The use of electrolysis in wastewater treatment of marine fish paste plant is discussed. The use of semipermeable membranes in electrolysis, and various flocculents, e.g. $AL_2(SO_4)_3$ and $FeCl_3$ is described." (Chemical Abstracts, 86, 126617a, 1977).

Shimoda, Y. et al., "Analysis of Waste Water Discharged from a Mackerel Processing Plant", Shizouka Ken Suisan Shikenjo Jigvo Hokoku (Japan), 78, 80

"Wastewater from mackerel cooking and pressing was analyzed for evaporation residue, fats, total N, COD, BOD, NaCl, and pH. Cooking water contained fats 23 and residue 186 kg/ton fish and water 7.3 m^3/ton fish. Water from pressing was 3.4 m^3 and fats 293 kg. (Chemical Abstracts, 87, 90247j, 1977).

Shimoda, Y. et al., "Waste Water Treatment after Processing of Marine Products. IV; Waste Water Treatment after Processing of Mackerel" Shizouka Ken Suisan Shikenjo Jigyo Hokoku (Japan), 61, (1974).

"Mackerel processing wastewater with BOD less than 4 kg/m^3 day was successfully treated by activated sludge, but at greater than 4.9 kg/m^3 day the treatment was incomplete. In a multistage process wastes having COD 200-700 approximately 200, and less than 200 ppm were treated for 71. 59, and 0% removal. A combination of activated sludge and trickling filter processes gave the best COD removal." (Chemical Abstracts, 87,106414z 1977).

Tagawa, S. et al., "Removal of Constituents from the Waste Water Discharged from "Kamaboko" Processing Plants by a pH Shifting Method," Suisan Daigakko Kenkyu Hokoku, (Japan) 24, 1, 37 (1975).

"The wastewater was adjusted to pH 2 with 3N HCL and neutralized for coagulation of protein substances. By this simple treatment n-hexane extractable matter was removed greater than 95 and suspended solids greater than 85%. The removal efficiency of COD was 60-70, protein N 70-80, and non-protein N less than 10%. There was an approximate linear relationship between COD and total, protein, and non protein N." (Chemical Abstracts, 87, 172326y, 1977).

Tagawa, S. et al., "Removal of Constituents from Waste Water Discharged from Mackerel Canning Plants by the pH Shifting Method," Suisan Daigakko Kenkyu Hokoku (Japan), 25, 1, 75 (1976).

"Waste water from mackerel canning plants was treated by adjustment of pH. The waste water was collected from cutting, filling, and steaming processes and a combined effluent from other sources in the plant. The removal efficiencies were n-hexane extractable matter and suspended solids greater than 95 and COD 50-60%. A close relation existed between COD and N concentrations in the waste water before and after the pH adjustment. After treatment greater than 90% of the total N in the wastewater was non-protein." (Chemical Abstracts, 87, 172325x, 1977).

Takagi, M. et al., "Comparatve Studies on the Effect of Coagulants on Activated Sludges from Fish Meat Processing Plants, I," Aichi-Ken Shokuhin Kogyo Shikensho Nempo (Japan), 14, 93, 1973.

"The testing coagulants included inorganic and organic polymers. The dehydration was tested by vacuum filtration. The inorganic coagulants showed the lowest water content in cake with lime 57.4% addition. The water content was 87-88% if lime and Fe^{2+} was added 17.2 and 2.9%, respectively. Alum was the most effective among inorganic coagulants. The addition of lime decreased the dehydration effect due to increased viscosity of sludge." (Chemical Abstracts, 85, 9915q, 1976).

Tanaka, Y. et al., "Purification of Waste Water from Marine Product Processing Plant," Japan Patent Disclosure No. 49-84048 (1974).

"Waste water from marine product processing plants is effectively purified by adding 50 ppm of an inorganic coagulant, adjusting the pH to 4.5-8.0, adding 5 ppm polyacrylamide-system coagulant, and then removing the resulting flocs. Thus, 0.5 kg of an $Al_2(SO_4)_3$ solution containing 8 g Al_2O_3/100 ml was mixed with 200 kg waste water (suspended substances 4,820, COD 1,400, BOD 6450 ppm) from a fish processing plant. After adjusting the pH to 6.5, 2 kg 0.1% aqueous polyacrylamide (molecular wt. 8,000,000) solution was added to the waste water to form flocs, which were removed by flotation. The waste water thus treated had suspended substances 337, COD 210, and BOD 710 ppm". (Chemical Abstracts, 82, 34855r, 1975).

Tashiro, H. "Treatment of Waste Water from Canneries." (Shizuoka Paper Exp. Stn., Shizuoka, Japan), PPM, 6, 3, 42 (1975).

"The composition, quantity, and treatment of waste water from canneries of fish, peaches, and oranges are described." (Chemical Abstracts, 83, 65144h, 1975).

Wada, T. et al., "Waste Water Treatment after Processing of Marine Products III; Waste Water after Processing of Skipjack," Shizouka Ken Suisan Shikenjo Jigyo Hokoku (Japan), 60 (1974).

"Steamed skipjack was drained. The drained wastewater was 33.6% fish wt. and contained crude protein 4.75, crude fats 0.34% and COD 12,000 ppm." (Chemical Abstracts, 87, 90246h, 1977).

APPENDIX D

GLOSSARY OF TERMS

activated sludge process: Removes organic matter from wastewater by introducing air (oxygen) into a vessel containing biologically active microorganisms.

aeration tank: A chamber for injecting air or oxygen into water.

aerobic organism: An organism that thrives in the presence of oxygen.

algae (alga): Simple plants, many microscopic, containing chlorophyll. Most algae are aquatic and may produce a nuisance when conditions are suitable for prolific growth.

ammonia stripping: Ammonia removal from a liquid, usually by intimate contact with an ammonia-free gas, such as air.

anaerobic: Living or active in the absence of free oxygen.

anionic: Characterized by an active and especially surface-active anion, or negatively changed ion.

aquaculture: The cultivation and harvesting of aquatic plants and animals.

average: An arithmetic mean obtained by adding quantities and dividing the sum by the number of quantities.

bacteria: The smallest living organisms which comprise, along with fungi, the decomposer category of the food chain.

bailwater: Water used to facilitate unloading of fish from fishing vessel holds.

batter: A flowing mixture of flour, milk, cooking oil, eggs, etc. for product coating.

biochemical oxygen demand (BOD): Amount of oxygen necessary in the water for bacteria to consume the organic sewage. It is used as a measure in telling how well a sewage treatment plant is working.

biological oxidation: The process whereby, through the activity of living organisms in an aerobic environment, organic matter is converted to more biologically stable matter.

biological stabilization: Reduction in the net energy level or organic matter as a result of the metabolic activity of organisms, so that further biodegradation is very slow.

biological treatment: Organic waste treatment in which bacteria and/or biochemical action are intensified under controlled conditions.

biomass: Mass or body of activated sludge microorganisms involved in the decomposition of wastes.

blow tank: Water-filled tank used to wash oyster or clam meats by agitating with air injected at the bottom.

BOD$_5$: A measure of the oxygen consumption by aerobic organisms over a 5-day test period at 20°C. It is an indirect measure of the concentration of biologically degradable material present in organic wastes contained in a waste stream.

breading: A finely ground mixture containing cereal products, flavorings and other ingredients, that is applied to a product that has been moistened, usually with batter.

brine: Concentrated salt solution which is used to cool or freeze fish.

BTU: British thermal unit, the quantity of heat required to raise on pound of water 1°F.

bulking sludge: Activated sludge that settles poorly because of low density floc.

byproducts: (As used in this report). Commodities which are produced as a secondary or incidental product of fish processing, but which are not suitable for human consumption (e.g., petfood, fish meal, fertilizer, etc.).

canned fishery product: Fish, shellfish, or other aquatic animals packed singly or in combination with other items in hermetically sealed, heat sterilized cans, jars, or other suitable containers. Most, but not all canned fishery products can be stored at room temperature for an indefinite period of time without spoiling.

carbon adsorption: The separation of small waste particles and molecular species, including color and odor contaminants, by attachment to the surface and open pore structure or carbon granules or powder. The carbon is "activated," or made more adsorbent by treatment and processing.

catalyst: A chemical element or compound which, although not directly involved in a chemical reaction, speeds up that reaction.

cation: Characterized by an active and especially surface-active cation, or positively changed ion.

cellulose: A polysaccharide, or complex carbohydrate, found in plant cell walls and naturally occurring in such fibrous products as cotton and kapok; used as raw material in many manufactured goods including paper.

centrifuge: A mechanical device which subjects material to a centrifugal force to achieve phase separation and then discharges the separated components.

chemical oxygen demand (COD): A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water.

chemical precipitation: A waste treatment process whereby substances dissolved in the wastewater stream are rendered insoluble and form a solid phase that settles out or can be removed by flotation techniques.

chitin: An abundant natural polyssacharide found in the shells of crustaceans, and in insect exoskeletons, fungi and certain other plants and animals.

chitosan: A deacetylized form of chitin, manufactured from chitin, and used in a variety of applications ranging from coagulation and ion-exchange wastewater treatments to adhesives and wound-healing sutures.

clarification: Process of removing undissolved materials from a liquid. Specifically, removal of solids either by settling, flotation, or filtration.

clarifier: A settling basin for separating settleable solids from wastewater.

coagulant: A material, which, when added to liquid wastes or water, creates a reaction which forms insoluble floc particles that adsorb and precipitate colloidal and suspended solids. The floc particles can be removed by sedimentation. Among the most common chemical coagulants used in sewage treatment are ferric chloride, alum and lime.

coagulation: The clumping together of solids to make them settle out of the wastewater faster. Coagulation of solids is brought about with the use of certain chemicals such as lime, alum, or polyelectrolytes.

comminutor (grinder): A device for the catching and shredding of heavy solid matter in the primary stage of waste treatment.

concentration: The total mass (usually in micrograms) of the suspended particles contained in a unit volume (usually one cubic meter) at a given temperature and pressure; sometimes, the concentration may be expressed in terms of total number of particles in a unit volume (e.g., parts per million); concentration may also be called the "loading" or the "level" of a substance; concentration may also pertain to the strength of a solution.

condensate: Liquid residue resulting from the cooling of a gaseous vapor.

contamination: A general term signifying the introduction into water of microorganisms, chemical, organic, or inorganic wastes, or sewage, which renders the water unfit for its intended use.

crustacea: Mostly aquatic animals with rigid outer coverings, jointed appendages, and gills. Examples are crayfish, crabs, barnacles, shrimp, water fleas, and sow bugs.

cyclone: A device used to separate dust or mist from a gas stream by centrifugal force.

DAF sludge: Also called float; the semi-liquid skimmings, containing solids, grease, oil and other contaminants, collected from the surface of a dissolved air flotation unit.

decomposition: Reduction of the net energy level and change in chemical composition or organic matter because of actions of aerobic or anaerobic microorganisms.

denitrification: The process involving the facultative conversion by anaerobic bacteria of nitrates into nitrogen and nitrogen oxides.

deviation, standard normal: A measure of dispersion of values about a mean value; the square root of the average of the squares of the individual deviations from the mean.

digestion: Though "aerobic" digestion is used the term digestion commonly refers to the anaerobic breakdown of organic matter in water solution or suspension into simpler or more biologically stable compounds or both. Organic matter may be decomposed to soluble organic acids or alcohols, and subsequently converted to such gases as methane and carbon dioxide. Complete destruction or organic solid materials by bacterial action alone is never accomplished.

dissolved air flotation (DAF): A process involving the compression of air and liquid, mixing to super-saturation, and releasing the pressure to generate large numbers of minute air bubbles. As the bubbles rise to the surface of the water, they carry with them small particles that they contact.

effluent: Something that flows out, such as a liquid discharged as a waste; for example, the liquid that comes out of a treatment plant after completion of the treatment process.

electrodialysis: A process by which electricity attracts or draws the mineral salts through a selective semi-permeable membrane.

end-of-pipe treatment: Treatment of wastewater after it has entered a sewer system and is no longer subject to recycle within a production process.

enzymatic digestion: Decomposition process which is assisted by the presence of naturally occurring organic catalysts called enzymes.

eviscerate: To remove the viscera, or entrails from the body cavity.

extruded: Shaped by passing through a die or mold such as fish sticks made from deboned fish flesh.

facultative aerobe: An organism that although fundamentally an anaerobe can grow in the presence of free oxygen.

facultative anaerobe: An organism that although fundamentally an aerobe can grow in the absence of free oxygen.

facultative decomposition: Decomposition of organic matter by facultative microorganisms.

fish fillets: The sides of fish that are either skinned or have the skin on, cut lengthwise from the backbone. Most types of fillets are boneless or virtually boneless; some may be specified as "boneless fillets."

fish meal: A ground, dried product made from fish or shellfish or parts thereof, generally produced by cooking raw fish or shellfish with steam and pressing the material to obtain the solids which are then derived.

fish oil: An oil processed from the body (body oil) or liver (liver oil) of fish. Most fish oils are a by-product of the production of fish meal.

fish silage: Proteinaceous byproduct resulting from the enzmatic digestion of fish wastes.

fish solubles: A product extracted from the residual press liquor (called "stickwater") after the solids are removed for drying (fish meal) and the oil extracted by centrifuging. This residue is generally condensed to 50 percent solids and marketed as "condensed fish solubles."

filtration: The process of passing a liquid through a porous medium for the removal of suspended material by a physical straining acton.

float: (Also called floating sludge) Solid material resulting from dissolved air flotation treatment which remains on the surface of a liquid or is suspended near the surface.

floc: Something occurring in indefinite masses or aggregates. A clump of solids formed in sewage when certain chemicals are added.

flocculation: The process by which certain chemicals form clumps of solids in wastewater.

floc skimmings: The flocculent mass formed on a quiescent liquid surface and removed for use, treatment, or disposal.

flume: An artificial channel for conveyance of a stream of water.

grease traps: A hydraulic device which removes grease from a waste stream.

grit chamber: A hydraulic device which removes sand, grit and other large, heavy particles from a waste stream.

groundwater: The supply of freshwater under the earth's surface in an aquifier or soil that forms the natural reservoir for man's use.

incineration: (As used in this report) The process of burning sludge to reduce the volume of material to an inert ash residue.

influent: A liquid which flows into a containing space or process unit.

in-plant controls: Technologies or management strategies which reduce the strength or volume of wastes discharged to end-of-pipe treatment systems.

ion: A free electron or other charged subatomic particle.

ion exchange: A reversible chemical reaction between a solid and a liquid by means of which ions may be interchanged between the two. It is in common use in water softening and water deionizing.

isoelectric point: Point at which the net electrical charge of particles is zero, thus causing destabilization which facilitates processes such as coagulation and flocculation.

kg: Kilogram or 1,000 grams, metric unit of weight.

kkg: Kilo-kilogram or 1,000,000 grams, metric unit of weight.

KWH: Kilowatt-hours, a measure of total electrical energy consumption.

lagoons: Scientifically constructed ponds in which sunlight, algae, and oxygen interact to restore water to a quality equal to effluent from a secondary treatment plant.

land disposal: (Also called land treatment) Disposal of wastewater into land with crop raising being incidental; the primary purpose is to cause further degradation by assimilation of organics and/or nutrients into the soil structure or the plants covering the disposal site.

landings, commercial: Quantities of fish, shellfish and other aquatic plants and animals brought ashore and sold. Landings of fish may be in terms of round (live) weight or dressed weight. Landings of crustaceans are generally on a live weight basis except for shrimp which may be on a heads-on or heads-off basis. Mollusks are generally landed with the shell on but in some cases only the meats are landed (such as scallops).

live tank: Metal, wood or plastic vessel with circulating seawater for the purpose of keeping fish or shellfish alive until processed.

m: Meter, metric unit of length.

mm: Millimeter = 0.001 meter.

mg/l: Milligrams per liter; approximately equals parts per million; a term used to indicate concentration of materials in water.

mgd: Million gallons per day.

microstrainer/microscreen: A mechanical filter consisting of a cylindrical surface of metal filter fabric with openings of 20-60 micrometers in size.

milt: Reproductive organ (testes) of male fish.

municipal treatment: A city or community-owned waste treatment plant for municipal and, possibly, industrial waste treatment.

nitrate, nitrite: Chemical compounds that include the NO_3^- (nitrate) and NO_2^- (nitrite) ions. They are composed of nitrogen and oxygen, are nutrients for growth of algae and other plant life, and contribute to eutrophication.

nitrification: The process of oxidizing ammonia by bacteria into nitrites and nitrates.

offal: A term for the waste portion of a fish, including head, tail, viscera, etc.

organic content: Synonymous with volatile solids except for small traces of some inorganic materials such as calcium carbonate which will lose weight at temperatures used in determining volatile solids.

organic matter: The waste from homes or industry of plant or animal origin.

oxidation pond: A man-made lake or body of water in which wastes are consumed by bacteria. It is used most frequently with other waste treatment processes. An oxidation pond is basically the same as a wastewater lagoon.

pH: The pH value indicates the relative intensity of acidity or alkalinity of water, with the neutral point at 7.0. Values lower than 7.0 indicate the presence of acids; above 7.0 the presence of alkalies.

physical-chemical treatment: A wastewater treatment process which relies on physical and chemical reactions, such as coagulation, settling, filtration and other non-biological processes, to remove pollutants.

polishing: Final treatment stage before discharge of effluent to a water course, carried out in a shallow, aerobic lagoon or pond, mainly to remove fine suspended solids that settle very slowly. Some aerobic microbiological activity also occurs.

ponding: A waste treatment technique involving the actual holdup of all wastewaters in a confined space with evaporation and percolation the primary mechanisms operating to dispose of the water.

ppm: Parts per million, also referred to as milligrams per liter (mg/l). This is a unit for expressing the concentration of any substance by weight, usually as grams of substance per million grams of solution. Since a liter of water weighs one kilogram at a specific gravity of 1.0, one part per million is equivalent to one milligram per liter.

press cake: In the wet reduction process for industrial fishes, the solid fraction which results when cooked fish (and fish wastes) are passed through the screw presses.

press liquor: Stickwater resulting from the pressing of fish solids.

primary treatment: Removes the material that floats or will settle in wastewater. It is accomplished by using screens to catch the floating objects and tanks for the heavy matter to settle in.

process water: All water that comes into direct contact with the raw materials, intermediate products, final products, byproducts, or contaminated waters and air.

processed fishery product: Plants and animals, and products thereof, preserved by canning, freezing, cooking, dehydrating, drying, fermenting, pasteurizing, adding salt or other chemical substances, and other commercial processes. Also, changing the form of fish, shellfish or other aquatic plants and animals from their original state into a form in which they are not readily identifiable, such as fillets, steaks, or shrimp logs.

pyrolysis: Physical and chemical decomposition of organic matter brought about by heat in the absence of oxygen.

receiving waters: Rivers, lakes, oceans, or other water courses that receive treated or untreated wastewaters.

recycle: The return of a quantity of effluent from a specific unit or process to the feed stream of that same unit. This would also apply to return of treated plant wastewater for several plant uses.

rendering: A reduction process involving the cooking, pressing and drying of animal waste materials to produce a dry protein meal.

retort: Sterilization of a food product at greater than 248°F with steam under pressure.

reuse: Water reuse, the subsequent use of water following an earlier use without restoring it to the original quality.

reverse osmosis: The physical separation of substances from a water stream by reversal of the normal osmotic process, i.e., high pressure, forcing water through a semi-permeable membrane to the pure water side leaving behind more concentrated waste streams.

roe: Fish eggs, especially when still massed in the ovarian membrane, taken and packaged as a delicacy for human consumption.

rotating biological contactor(RBC): A waste treatment device involving closely spaced light-weight disks which are rotated through the wastewater allowing aerobic microflora to accumulate on each disk and thereby achieving a reduction in the waste content.

rotary screen: A revolving cylindrical screen for the separation of solids from a waste stream.

sand filter: Removes the organic wastes from sewage. The wastewater is trickled over a bed of sand. Air and bacteria decompose the wastes filtering through the sand. The clean water flows out through drains in the bottom of the bed. The sludge accumulating at the surface must be removed from the bed periodically.

sanitary landfill: A site for solid waste disposal during techniques which prevent sector breeching, and controls air pollution nuisances, fire hazards and surface or groundwater pollution.

screen: (As used in this report) A device with openings, generally of uniform size, used to retain or remove suspended or floating solids in flowing water or wastewater and to prevent them from entering an intake or passing a given point in a conduit. The screening element may consist of parallel bars, rods, wires, grating, wire mesh, or perforated plate, and the openings may be of any shape, although they are usually circular or rectangular.

secondary products: (as used in this report) fish processing products which, although not the primary product, are still suitable for human consumption (e.g., fish sticks).

secondary treatment: The second step in most waste treatment systems in which bacteria consume the organic parts of the wastes. It is accomplished by bringing the sewage and bacteria together in trickling filters or in the activated sludge process.

sedimentation tanks: Help remove solids from wastewater. The wastewater is pumped to the tanks where the solids settle to the bottom or float on top as scum. The scum is skimmed off the top, and solids on the bottom are pumped out for subsequent processing or disposal.

settleable matter (solids): Determined in the Imhoff cone test and will show the quantitative settling characteristics of the waste sample.

settling tank: Synonymous with "Sedimentation Tank".

sewers: A system of pipes that collect and deliver wastewater to treatment plants or receiving streams.

shock load: A quantity of wastewater or pollutant that greatly exceeds the normal discharged into a treatment system, usually occurring over a limited period of time.

shuck: A process used to remove the shells from oysters and clams.

sludge: The solid matter that settles to the bottom of sedimentation tanks and must be handled by digestion or other methods to complete the waste treatment process.

sludge dewatering: The process of removing a portion of the water in sludge by any method such as draining, evaporation, pressing, vacuum filtration, centrifuging, exhausting, passing between rollers, acid flotation, or dissolved-air flotation with or without heat. It involves reducing from a liquid to a spadable condition rather than merely changing the density of the liquid (concentration) or drying (as in a kiln).

solubles: The material which results after processing that was dissolved or able to pass into solution in the stickwater. This residue can be incorporated into fish meal or sold separately as a byproduct.

species (both singular and plural): A natural population or group of populations that transmit specific characteristics from parent to offspring. They are reproductively isolated from other populations with which they might breed. Populations usually exhibit a loss of fertility when hybridizing.

stickwater: Water and entrained organics that originate from the draining or pressing of steam cooked fish products.

sump: A depression or tank that serves as a drain or receptacle for liquids for salvage or disposal.

tertiary waste treatment: Waste treatment systems used to treat secondary treatment effluent and typically using physical-chemical technologies to effect waste reduction of specific pollutants. Synonymous with "Advanced Waste Treatment."

Improving the Economics
of
Crustacean-waste Disposal

Peter M. Perceval and W.E. Nelson
CHI-AM International, Inc.
16. E. Southampton Ave.
Hampton, Virginia 23669

The highly valuable segment of the U.S. fishing industry which processes crustaceans - shrimp, crab, lobster and crayfish - has always been plagued with the problem of disposing of the tremendous quantities of solid wastes it generates. The problem has become more serious in recent years with the increase in demand for these species, the development of new fisheries, and the necessary implementation of water, air and solid waste pollution control regulations. Various solutions have been suggested but few, if any of them, meet the necessary requirements of being environmentally sound, economically viable and applicable year-round in areas which range in temperature from the highs of the Gulf Coast to the lows of Alaska, and in locations as different as metropolitan complexes at one extreme and remote fishing communities at the other.

The two major inputs to solving the problem have usually come from either the industry itself or from those institutions concerned with marine resources.

Under the circumstances it is quite understandable that the industry's approach has generally been one of seeking the least expensive means of getting rid of the troublesome materials. In many locations the dehydration plants that have resulted from this approach are now unable to achieve sufficient revenues for their relatively crude product to compensate for rapidly increasing costs - as is the case in the crab meal industry. The problems that are now being faced by these plants, some of which have already gone out of business, naturally discourage other locations from attempting this particular solution to the problem.

The institutional approach has generally been to seek the highest possible value that could be achieved from crustacean wastes - through the chemical extraction of chitin, chitosan and by-products. However, after some forty years of attempts at commercialization, this solution has yet to be proven economically viable and the history of repeated pilot-plant failures discourages many potentially-interested chemical process industries from further ventures in this direction.

A Different Approach

A careful study of the conventional disposal practises and meal plant operations together with an understanding of some of the unique properties of chitin suggests that there is considerable merit in adopting an approach which should generate more revenue than currently received for crustacean meals; which benefits from some of the valuable features of the chitin contained in the wastes; and which lends itself to implementation by the fishing industry itself - as opposed to requiring manufacturing participation from the chemical process industry as is the case with chitin and chitosan extraction.

Basically this approach can be divided into two complementary segments: (a) increasing the profitability of existing dehydration plants, especially those which handle wastes with a high proportion of inorganic material such as result from crab processing. (b) improving crustacean waste processing to provide an economically viable method for areas where no such option exists currently.

Problems of Conventional Dehydration

Three undesirable features of existing crustacean meal processing suggest the need for change. First, in almost all locations which currently practise this means of disposal, crude dehydration methods are employed which usually involve direct flame drying of the ground, or frequently unground, waste materials. Such drying methods are not conducive to attainment of highest market values for the resulting products. Any potential increase in value from pigmentation, such as is the case with shrimp waste, is considerably reduced by such crude drying. Second, in the case of those wastes with a high inorganic content, such as crab waste,the loss in meal value due to crude drying is compounded by a very unfavorable calcium to phosphorous ratio which markedly restricts levels of incorporation in feedstuffs.Third, because of the crude dehydration methods that are generally employed, air pollution problems are almost inevitable. In order to overcome these problems considerable additional expense is now being incurred for major control equipment such as proper scrubbers. Implementation of the Clean Air Act Amendments of 1977 requires a mandatory assessment of "non-compliance penalties" against nearly every violating source of air pollution after August 7, 1979.

In summary then, avoidance of air pollution penalties, the requirement for effective disposal techniques and the necessity for increased by-product revenues all combine to suggest the need for a change in methods of dehydrating crustacean wastes.

Improved Dehydration Methods

Various alternative dehydration systems have been available for some time but few, if any, appear to have been adopted for drying crustacean wastes probably because of higher initial cost. A good example of such an improved system was announced in NATIONAL FISHERMAN, May, 1979 (1). This report concerns the availability from within the fishmeal industry, of an indirect-heat, continous vacuum dryer which, because of its gentler drying characteristics, should permit marketing of much more valuable shrimp meal or crab meal than is the case with the higher temperature direct heat, flame dryers. Shrimp meal produced by this process has brought offers of prices more than double those received for conventionally dried meal and the process does not result in air pollution according to the manufacturers (2). One of the new units capable of producing .8 tons per hour of dried crustacean meal at 8-10% moisture is quoted as costing approximately $100,000.

Decalcification

In the case of meals produced from species of crab, lobster and crayfish, it is generally recognized that if most of the shell fraction could be removed inexpensively a considerably higher price could be attained for the protein fraction. A method of such "decalcification" was proposed by Rutledge of L.S.U. (3) in 1971.

Rutledge's pioneering work involved decalcifying Blue Crab and Freshwater Crayfish meals by drying to a moisture level of 6% or less, grinding through a Wiley mill with a ¼" screen, and sieving through a No. 12 U.S. standard mesh screen. Table I from Rutledge's work shows proximate analyses of crab and freshwater crayfish waste before and after separation. Table II from the same source, lists separation processing efficiency.

Protein content of the meals was almost doubled by such processing and calcium levels were reduced by as much as 68%. Rutledge pointed out that, "such processing will tend to reduce the imbalance between calcium and phosphorus, as well as increase the protein content" - both of which factors would raise the value of such crustacean meals. He concluded that, "if it is feasible to dry such materials, additional cost of milling and screening should be nominal." Figure III demonstrates what would be the combined value attainable from such a separation process as described by Rutledge, assuming that each fraction is worth the price in cents per pound indicated at the top and side of the table. It does not seem unreasonable to expect values in excess of 15 cents per pound for such an improved meal product with 58.4% protein. The protein value and amino acid balance approximate those of fish meal which is currently valued at around $400 per ton.

Admittedly, an attempt to displace fish meal in some

From James E.Rutledge 1971 (3).

Table I Proximate Analyses of Crab and Freshwater Crayfish Waste Before and After Processing (a)

Constituent	Before Processing		After Processing	
	Blue Crab	Crayfish	Blue Crab	Crayfish
	Percentages		Percentages	
Moisture	4.5	5.7	8.2	6.4
Protein (b)	24.0	28.1	58.4	58.5
Fat	2.0	4.4	2.7	6.0
Chitin	12.9	12.5	2.6	2.1
Ash	56.0	44.0	20.5	16.8
Calcium	17.0	18.0	7.5	5.7
Phosphorus	1.7	1.2	1.4	0.9

(a) Average of 20 analyses (b) Corrected for chitin

Table II Processing Efficiency (a)

Determination	Blue Crab	Crayfish
	Percentage	
Skeletal material in waste prior to processing (b)	80.2	75.4
Skeletal material in meal after processing (b)	21.6	15.8
Processing efficiency	73.0	79.0

(a) Average of 20 analyses (b) Percent of total dry material

Note: 60 to 65 % of total waste material is separated as shell in the course of processing.

1250 POUNDS SHELL FRACTION = 62.5%

750 lbs
IMPROVED
PROTEIN
= 37.5%

¢ per lb	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	125	137.5	150	162.5	175	187.5	200	212.5	225	237.5	250	262.5	275	287.5	300
16	132.5	145	157.5	170	182.5	195	207.5	220	232.5	245	257.5	270	282.5	295	307.5
17	140	152.5	165	177.5	190	202.5	215	227.5	240	252.5	265	277.5	290	302.5	315
18	147.5	160	172.5	185	197.5	210	222.5	235	247.5	260	272.5	285	297.5	310	322.5
19	155	167.5	180	192.5	205	217.5	230	242.5	255	267.5	280	292.5	305	317.5	330
20	162.5	175	187.5	200	212.5	225	237.5	250	262.5	275	287.5	300	312.5	325	337.5
21	170	182.5	195	207.5	220	232.5	245	257.5	270	282.5	295	307.5	320	332.5	345
22	177.5	190	202.5	215	227.5	240	252.5	265	277.5	290	302.5	315	327.5	340	352.5
23	185	197.5	210	222.5	235	247.5	260	272.5	285	297.5	310	322.5	335	347.5	360
24	192.5	205	217.5	230	242.5	255	267.5	280	292.5	305	317.5	330	342.5	355	367.5
25	200	212.5	225	237.5	250	262.5	275	287.5	300	312.5	325	337.5	350	362.5	375

Figure III

COMBINED VALUE IN DOLLARS PER TON SEPARATED, BASED UPON 37.5% IMPROVED PROTEIN FRACTION AND 62.5% SHELL RESIDUAL FRACTION.

markets might run into the problem of insufficient quantity of the improved crustacean meal to meet the high-volume requirements of major pet food producers. Never-the-less there are some other lower volume markets, such as aquaculture, wherein the supply and demand factors should be in better balance, and the special properties of a marine-source protein are in great demand.

Processing in Isolated Locations

In certain isolated locations where even an improved dehydration plant might be considered a doubtful economic proposition, either because of fuel costs or added transportation-to-market costs for the products, utilization of either a Paoli or Baader type meat-bone separator has been found to be highly effective for extracting the proteinaceous portion of crustacean wastes which could then be block frozen for distant markets (4). It has been demonstrated (5) that a Paoli machine can obtain 32% of the total weight of moist,ground blue crab waste as a protein fraction with an analysis of 56.72% protein and 16.93% ash (dry basis). If the market justifies it the shell fraction resulting from such a separation system would be considerably cheaper to dry after most of the adventitious protein has been removed. Furthermore the particle size would already have been reduced during the grinding which, with most species of waste, is required prior to separation by this type of machine.

In summary there is a considerable body of evidence to demonstrate that crustacean wastes could be better processed in a variety of methods any one of which should result in a pricing structure for the resultant protein product that approximates that of fish meal.

The Residual Shell Fraction

The shell fraction that would result from perfect mechanical separation consists of the cuticle with its associated chitin, calcium, and bound proteins. Much is already known about crustacean cuticles partly as a result of the research that has been done in connection with chitin and chitosan extraction, and also from another body of the literature which is involved with the cuticle for purely scientific reasons.

In arriving at some minimum attainable values for this shell fraction the approach taken was to consider: (a) its basic structure; (b) those properties of chitin itself which have suggested market potential; (c) chitin manufacturing procedures. In the isolation and purification of chitin, accompanying calcium and proteins are dissolved away by dilute acid and alkali respectively. What is left is the chitin which is insoluble in dilute acids, and cold alkalis of any concentration (16). It has been noted frequently that when demineralization precedes deproteination a considerable portion of the bound protein is removed along with the calcium (11).

All of these factors are then considered in the context of possible market areas wherein a pollution application might benefit from utilization of the dried shell fraction, at its original grind size, or further pulverized.

Referring again to Figure III, for example, it is obvious that a price of even 10 cents per pound for the shell fraction radically affects the economics of a dehydration plant if one can attain 15 cents per pound for the protein fraction. In fact the combined revenue per ton of meal separated almost doubles, increasing from approximately $120 under the present drying and marketing system to $237.50 in the new concept. Such added revenue potential for existing meal plants should improve the economics sufficiently to justify installation of needed air pollution control equipment. It should also justify establishment of newer, and more efficient, environmentally acceptable plants at locations which currently have no disposal method.

The Cuticle

B.S. Welinder (6) reported that crab cuticle (Cancer pagurus) consists of three layers: a combined epi - and exocuticle, an endocuticle, and a membranous layer (Figure IV). The weight distribution between the layers showed that the dominating layer is the endocuticle. Chitin distribution was as follows:

Epicuticle/Exocuticle	9%
Endocuticle	84%
Membranous layer	7%

Lockwood (7), and others have established the fact that the membranous layer of crustacean cuticle is uncalcified. It has also been determined that the protein associated with this layer is arthropodin - not the tanned protein, sclerotin (8 and 9). Thus the protein in this layer is more readily solubilized

FIGURE IV
Decalcified *Cancer pagurus* cuticle
From B.S.Welinder 1975 (4)

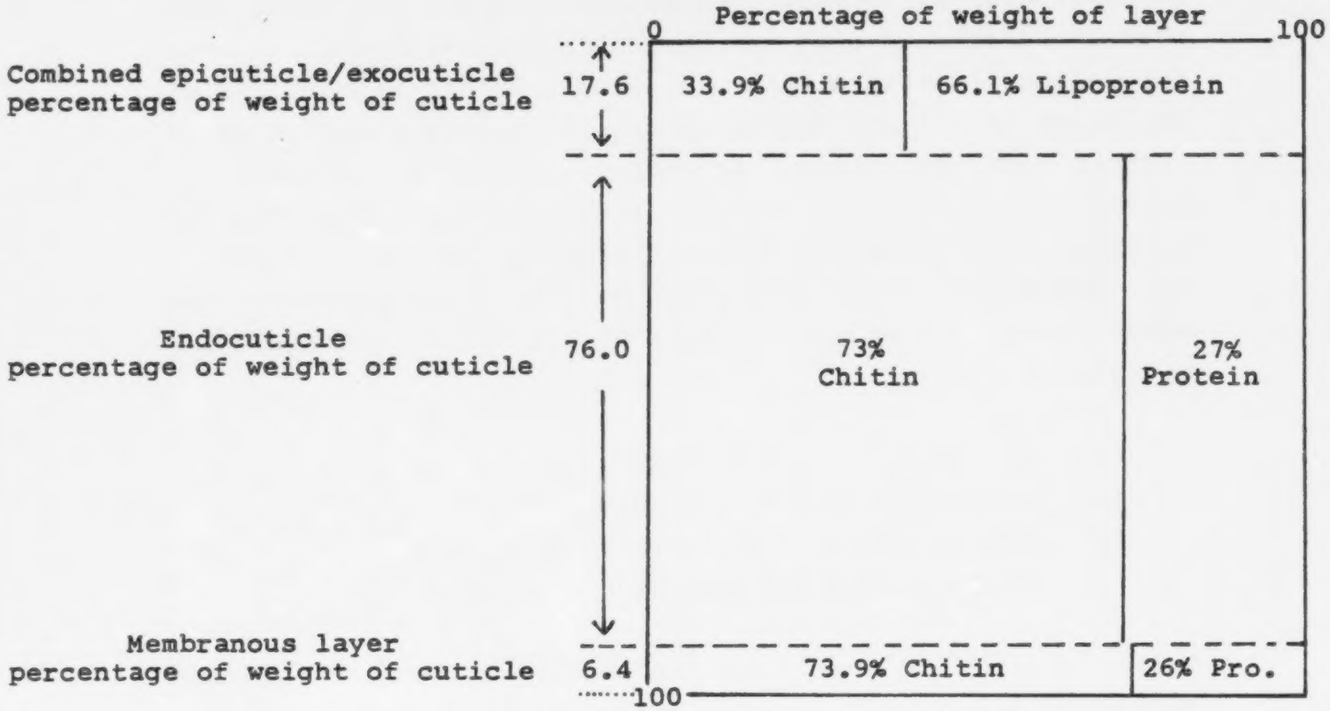
Percentage of weight of layer
0
100
Combined epicuticle/exocuticle percentage of weight of cuticle
17.6
33.9% Chitin
66.1% Lipoprotein
Endocuticle percentage of weight of cuticle
76.0
73% Chitin
27% Protein
Membranous layer percentage of weight of cuticle
6.4
73.9% Chitin
26% Pro.
100

FIGURE IV a

Solubility of layers of previously decalcified *Cancer* cuticle
(Numbers in brackets represent weight loss expressed as percentage of the protein present in the various layers)

	100% HCOOH	1M CH_3COOH
Combined epicuticle/exocuticle	36.1% (58.1%)	21.7% (34.9%)
Endocuticle	28.2% (104.4%)	15.7% (58.1%)
Membranous layer	30.9% (118.0%)	20.1% (76.9%)

Note: Numbers exceeding 100 indicate some chitin was brought into solution.

or caused to dissociate from the chitin without having to resort to harsh chemical treatment. While the middle layer (endocuticle) is heavily impregnated with calcium salts, the protein associated with the chitin is also arthropodin. The outer layer (combined epi- and exocuticle) is also calcified but seems to contain the tanned protein, sclerotin, in association with its chitin. According to Neville (10) and others,the epicuticle itself is non-chitinous. Thus the 9% of total chitin that Welinder (6) reports in the combined epi- and exocuticle must lie on one side of this layer - the exocuticle. In summary then, the crab cuticle usually contains:

(a) no chitin in its outermost layer
(b) no calcium in its innermost layer
(c) approximately 90% of its total chitin in the middle and innermost layers

Recent work by Perceval (11) has confirmed that, as might be expected, the cuticle of blue crab (Callinectes sapidus) is layered in much the same manner as in the species (Cancer pagurus) studied by Welinder. Therefore it seems reasonable to expect that chitin distribution between the three layers will also be somewhat similar.

Whether or not the arthropodin of the membranous layer and endocuticle is as easy to solubilize in water, or after heat treatment, as has been suggested by Kent (12) remains to be determined. However, Welinder (6) states that much, if not all, of this protein is soluble is acid (see also Figure IVa). Moreover the techniques of chitin extraction prove that cuticular proteins are solubilized by weak alkali solutions, and the associated calcium is solubilized by dilute acid.

The Effect of Pulverization

If the dried cuticle (shell fraction) is now pulverized and the resulting material is used as a liquid-phase adsorbent it seems highly probable that certain inherent properties will become available. The vastly increased surface area should encourage some adsorption, the presence of the proteins might be expected to bring about some chelation of heavy metals (13), and the calcium would reduce the acidity of a low pH effluent solution. Furthermore, as solubilization and dissociation of the calcium in the upper layers and the arthropodin of the middle and innermost layers, continues in an acidic effluent a maximum of 90% of the total available chitin could become available for chelation and/or ion exchange.

Powdered Shell Compared to Chitin and Chitosan

Many, if not all, of these assumptions are borne out by work that was performed recently at the National Taiwan University (14). At that institution Tsu-Chang Hung and Sharon Li-Ming Han tested commercially extracted chitin and chitosan against powders they prepared from shellfish-shell as adsorbents for heavy metal ions from aqueous solutions. They found that the adsorbent capacity and selectivity for metal ions on shrimp-shell powder was almost the same as for extracted chitin and chitosan. They also found that there was no significant difference between powders prepared from the shells of different species of shrimp and crabs. The degree of metal ion adsorption varied with pH value and was also a function of time. Significantly, they report that at pH 3, after one hour of stirring, the degree of adsorption on the powder was higher than either chitin or chitosan for mercuric ions, cuperic ions, zinc ions, lead ions and cadmium ions. Another interesting finding was that the powder itself, the same material subjected to acid-treatment with 13.5% HCl, the powder alkali-treated with 5% NaOH, the powder with combined acid and alkali treatments as above, and the commercially extracted chitin and chitosan all adsorbed in excess of 85% mercuric ions regardless of changing pH and with only a slight difference in effectiveness. The Taiwanese scientists experimented with a species of crab (Portunidae tribercultatus) which comes from the same over-all family as the blue crab (Callinectes sapidus). Assuming the adsorbent capacity and selectivity of powdered shrimp and crab shell from waste products of the United States fisheries approximates the levels obtained in the Taiwan experiments, suggests a potential marketability in such industrial effluent situations as mining and metallurgy, paints and dyes, pesticides, electrical and electronic, and battery manufacture.

This potential has already been the subject of preliminary investigation by one of the major U.S. companies involved in water pollution control. Initial testing performed at Virginia Polytechnic Institute and State University (15) also has produced encouraging results in adsorption of lead.

Other Areas with Utilization Potential

The preferential affinity of chitin for Chromium (VI) at pH 2.5 discussed by Muzzarelli (16) also suggests the wisdom of testing the material in other industrial settings such as electro-plating.

The affinity of chitin for actinide series elements such as Uranium and Plutonium reported by Muzzarelli (16) and Silver (17) respectively, offers another fertile field for testing the powdered shell fraction on nuclear industry effluent streams which, in many instances, are acidic. In a neutral or alkaline nuclear industry effluent situation the know affinity of calcium for strontium might also prove beneficial.

Richards and Cutkomp (18) discussed the correlation between possession of a chitinous cuticle and sensitivity to DDT. Lord (19) reported on the sorption of DDT and its analogues, and there have been other publications on the general subject of an affinity between chitinous cuticle and chlorinated hydrocarbons. A very recent paper by Hiraizuma, Takashi and Nishimura (20) examines adsorption of Polychlorinated Biphenyl onto sea bed sediment, marine plankton and other adsorbing agents. Those authors found that dehydrated zooplankton adsorbed PCB with nearly the same concentration factor as Amberlite XAD-4 and considerably more than aged granular activated carbon. They state that the effect of organic content upon the magnitude of the concentration factor cannot be denied. Copepods possessing chitinous exoskeleton are the dominant grouping in most samples of zooplankton and it is interesting to speculate whether possession of a chitinous cuticle might not be the main, or at least a major contributor to the results obtained in the Japanese work. A preliminary investigation of this possibility is also getting underway and the results might help define yet another promising market potential for powdered crustacean shell.

Benefiting from Nature's Processes

Subramanian (21) and Martin (22) discuss the role of chitin contained in moulted exoskeletons as a means of transport of metals to the world's oceans and their sediments. One might reasonably expect that adsorption of the metals they examined, and others, would be enhanced on powdered crustacean shell due to the fact that the moulted exoskeletons often contain less chitin than the cuticle possesses at other stages in the crustacean life cycle (23).

Puquegnat, Fowler, and Small (24) reported that the maximum Zn requirements for marine organisms is 2.7μg Zn/g wet weight. They thus attributed the higher stable-zinc concentrations of Euphausia pacifica to adsorption-exchange, since 14 times as much was found in just-moulted exoskeletons as in the muscle tissue of the same individuals. Fowler, Small, and Dean (25) reported that Zn uptake by dead and living euphausids was statistically similar and thus, neither directly nor indirectly related to metabolism; the largest Zn fraction was always associated with the exoskeleton.

Martin (22) lists concentration factors for the zooplankton samples he analyzed as:

Element	Concentration Factor
Pb	197,000
Fe	14,400
Cd	6,000
Zn	5,100
Co	3,200
Ni	2,500
Mn	1,650
Cu	1,630

Biodeterioration

An important point that is made by Subramanian and Martin (21 and 22), and discussed in a different context by Berkeley (26) and others has to do with the biodeterioration of chitin - and therefore crustacean shell. In some pollution control applications that have been proposed for pulverized shell it is obvious that prolonged immersion in the presence of chitinolytic microorganisms will result in complete degradation of the particles whereupon the entrapped pollutant would again be released to the environment. Hood and Meyers (27) found, as would be expected, that the rate of decomposition of cuticle increased as particle size decreased. They suggest that the protein content of the untreated chitin (cuticle) may provide an attractant, allowing the substrate to be more rapidly colonized and degraded after 4 days of the *in situ* studies they conducted. Essentially all of the substrate had been degraded by the end of the 23rd day. While this biodeterioration factor must be considered in many applications for chitin - and therefore powdered shell fraction - it should not prove to be an insuperable problem because the content of some of the effluent streams under consideration would make it rather unlikely that microbial activity would be high. Particle size and duration of its exposure to the sources of biodeterioration can be controlled to allow sufficient time for maximum removal of pollutant and minimum degradation by microorganisms.

Possible Pricing Structure for Pulverized Shell Fraction

If powdered crustacean shell fraction, produced in some manner as suggested herein, could approximate the cost-effectiveness of activated carbon as an adsorbent, or that of Amberlite

XAD-4 with its affinity for chlorinated pesticides (28), the price to the user would be somewhere around 40 cents per pound in the former case and 80 cents per pound in the latter. However both of the materials used for this comparison are usually capable of being regenerated - a cost-saving feature which is also possible for chitin but might prove impractical for the powdered shell. It would seem therefore that once-through situations would be the best targets for decontamination applications with the proposed new product. Even in this setting, with a necessarily lowered market price, it is not unlikely that worthwhile markets will develop which could consume all the powdered shell that might be produced from current and future crustacean wastes in the United States especially when the product is perfected as to particle size and quality control. The optimum markets and pricing structures remain to be determined, but, referring to Figure III it can readily be seen how a given value for the shell fraction significantly affects the overall economics of crustacean waste disposal in this scheme of operation.

A Minimum-Investment Process

Simplicity of the separation process, the prospect of some profitability for the crustacean-processing industry, and the interest already generated all suggest that this type of disposal technique may one day become the method of choice for this industry. Other obvious separation techniques should no doubt be considered. However, some of these more sophisticated methods may result in elevating production costs to the point where the shell fraction might not compete with possible alternative materials or processes. The problem that has to be solved is waste disposal in an extremely valuable segment of the fishery industry - in some instances located at great distance from major urban centers. The solution should be one that requires minimum investment in production equipment and systems necessary to maintain quality control of the ultimate products.

Finally, other possible market areas will likely occur to those familiar with the unique properties of chitin - some potentially more valuable than discussed here, and some less - however the suggestions herein are not intended to be all-inclusive. The purpose of this paper is to point out that there appears to be a viable alternative disposal scheme for the crustacean industry and that it will likely be one that is well-worth exploring. In fact it is the subject of considerable work that is either ongoing or was performed many years ago.

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NFPA **National Food Processors Association**
1133 Twentieth Street N.W., Washington, D.C. 20036
Telephone 202/331-5900

Agricultural and Environmental Affairs
Edwin A. Crosby, Ph.D.
Senior Vice President
202/331-5967
Jack L. Cooper
Director,
Environmental Affairs
202/331-5969
Raymond F. Altevogt, Ph.D.
Assistant Director,
Agricultural Affairs
202/331-5968

April 17, 1979

Mr. Calvin J. Dysinger
Effluent Guidelines Division (WH-552)
U. S. Environmental Protection Agency
401 M Street, S. W.
Washington, D. C. 20460

Regarding: Comments on the February 1979 report titled Technology for Seafood Processing Waste Treatment and Utilization, Section 74 Seafood Processing Study, prepared for EPA by the E. C. Jordan Company, Portland, Maine, under contract No. 68-01-4931.

Dear Mr. Dysinger:

The National Food Processors Association, formerly the National Canners Association, is a nonprofit trade association with approximately 650 members who pack about 90 percent of the total United States production of canned food for human consumption. The seafood processing members of our Association appreciate this opportunity to comment on the above report.

The only comments submitted at this time are our specific comments on individual parts of the report. Our overall general comments on the scope of the report, assumptions made, and other factors will be provided to you as soon as they can be prepared, and reviewed by the industry and counsel.

The attached specific comments are presented by page, paragraph, and sentence number.

Sincerely,

Jack L. Cooper

enclosure

cc: Effluent Guidelines Subcommittee for Seafoods
Brian Leamy
Vince Evich
Dave Ballands
Tony Nizetich

April 17, 1979

SPECIFIC COMMENTS
by the
NATIONAL FOOD PROCESSOGS ASSOCIATION
on the Report titled
TECHNOLOGY FOR SEAFOOD PROCESSING WASTE TREATMENT AND UTILIZATION
dated
FEBRUARY 1979
Prepared by the
E. C. JORDAN COMPANY, PORTLAND, MAINE
for the
U. S. ENVIRONMENTAL PROTECTION AGENCY
under EPA Contract No. 68-01-4931

Our comments are presented by page, paragraph, and sentence number:

ii, 1, 1, The last word of the first sentence should be "waters" instead of the term "wastes."

ii, 2, 2, This sentence should be rewritten to read as follows:

> For most of the industry, existing waste management practices are in compliance with EPA's nationally promulgated effluent guidelines and additional more stringent requirements necessary to achieve locally derived water quality standards.

The industry does not regard its existing waste management practices as "poor"; nor does the industry regard its existing waste management practices as resulting in the wasting of significant portions of the raw material brought to shore. The industry currently utilizes as much material from the incoming raw fish or shellfish as is possible. Since there are no existing markets for unutilized parts of the incoming raw material, these residuals must be handled as waste.

ii, 2, 3, We disagree with the statement that improved handling of the waste materials can result in more complete utilization, the production of salable by-products, or reduced waste volumes and reduced associated environmental control costs. Just because you are able to handle a waste better is no assurance that more of that material can be utilized or that it can be sold for a reasonable return of or on the investment. Improved handling is also no guarantee that the volume of waste generated or the costs associated with its disposal can be reduced. Accordingly, this sentence should be deleted.

ii, 3, We recommend that this paragraph be rewritten to read as follows:

> Large year-round seafood processors, such as large tuna canneries and major fish meal plants, practice waste management and environmental control methods, which include effective controls on water use, water recycling techniques, and recovery and use of raw materials not

incorporated as part of a human food product line, such as for the production of pet food and meat by-products. Portions of the incoming raw material which cannot be converted into human food or by-products, must be disposed of as waste.

iii, 2, 2, We disagree with the statement that improved waste treatment and disposal methods are required to reduce the impact of these wastes on the environment. This is a generalized statement implying that the disposal of seafood processing wastes adversely impact the environment and thus must be removed from the environment at all locations. This implication is improper particularly since the focus of the Section 74 Seafood Processing Study is to assess and determine the effects of seafood waste discharges into marine waters. The contractor has prejudged the conclusion of the report that seafood processing wastes adversely impact marine waters. We strong disagree with this implication and recommend that this sentence be deleted. In fact, in at least one area, Terminal Island, California, a recent study by the Institute for Marine and Coastal Studies of the Allan Hancock Foundation, Los Angeles, California, has concluded that controlled discharges of cannery waste may be beneficial to marine life by providing nutrients for the food web. We understand that the complete report is at the printers and will be submitted to EPA soon.

We recommend that this paragraph be rewritten to read as follows:

> The most applicable technology for seafood processing plants located in remote parts of Alaska is grinding followed by direct discharge. For seasonal seafood processing plants in the contiguous states the most applicable technology is screening. For the tuna and fish meal processing plants, the highest level of treatment that should be required is dissolved air flotation. Other, more advanced technologies are available but are not applicable to the industry. Where the achievement of locally derived water quality standards require treatment beyond the levels indicated above, seafood processing plants could investigate a number of more complex wastewater treatments. Where more complex alternatives are being considered, seafood processing plants should examine in-plant modifications for opportunities to reduce the quantities and volumes of wastes generated.

iii, 3, 1, This paragraph begins with the statement "To reduce its environmental impact, the seafood industry should . . ." Again, the contractor has concluded that there is an adverse environmental impact due to the discharge of seafood processing wastes into marine waters. If this sentence is to be left in, we recommend that it be rewritten to read as follows:

> At those specific sites where adverse impacts due to the discharge of seafood processing waste need to be mitigated, affected seafood processing plants should investigate improvements to their water and waste management practices, which may include efforts in the area of by-product manufacturing, and wastewater treatment and solids disposal technologies.

1, 2, 1, The scope of effort states that the contractor was to identify and evaluate certain technologies. We concur that the report does indeed identify many technologies; however, we disagree that the report "evaluates" any of them. Accordingly, we recommend that the words "and evaluate" between the words "identify" and "technologies" be stricken from this sentence.

The major purpose of the Section 74 Seafood Processing Study was to evaluate the effects of seafood processes which discharge into marine waters. Consequently, the scope of effort on page 1 should include an evaluation of the technologies necessary for the proper disposal of seafood processing wastes into marine waters. However, the report is completely void of any such evaluation.

2, 1, 1, In the scope of effort, the contractor states that costs were to be developed for programs to achieve waste reductions through in-house management and end-of-pipe treatment techniques. While some costs are shown, no source or reference is cited for many of them. For example, see Tables 5, 6, and 7. Without specific reference citations as to how these costs were developed, it is impossible to comment on their validity.

2, 1, 2, The report does emphasize the utilization of seafood processing wastes for human consumption; however, little or no discussion is presented on the problems of obtaining FDA approval for the marketing of by-products made from seafood processing wastes for human or animal consumption. Problems in obtaining FDA approval should be investigated and included in the report. Also, this sentence lumps demonstrated technologies such as the production of fish meal and fish oil with speculative and unestablished markets for new human consumption and chitin/chitosan products. Throughout the report, reference to the production of new products for human consumption and other theoretically producable products such as chitin/chitosan should be clearly identified and presented as possible alternatives that may be available sometime in the future but that they are not presently available. A reader of the paragraph as written could conclude that the production of by-products for human consumption and chitin/chitosan are just as available as by-products such as fish meal and fish oil. This simply is not true and should not be implied in the report.

While the seafood processing industry looks forward to the development of new by-products from seafood wastes, we caution the contractor to keep in mind the following economic and regulatory facts: (1) fish and shell meal plants not processing a primary fish meal product such as menhaden are net loss operations; (2) the chitin/chitosan plant in Brownsville, Texas, went into financial backruptcy; (3) uses of protein by-products derived from seafood wastes, i. e. DAF sludges, by the use of polymers and chemicals will be stringently regulated by the U. S. Food and Drug Administration; and (4) neither chitosan nor any other polymeric agent currently used in DAF systems has FDA approval.

Considering the economic and regulatory constraints on the use of chitosan and any by-products recovered with its aid, caution is urged in promoting chitosan as a solution to seafood waste disposal. This concern has apparently been recognized by the economic contractor (DPRA) who concludes that chitosan is not economically feasible under present conditions.

If the contractor is predisposed to urge recovery of protein materials from seafood wastes to serve as feed and food supplies, we fail to see why the contractor has failed to recognize the nutritional value of feeding these materials to marine organisms.

2, 1, 3, The statement is made that an economic study is being "undertaken by another contractor." The other contractor should be identified.

2, 2, The report does not address technologies for discharging or dispersing seafood processing wastes to marine waters. We strongly recommend that the report be revised to address the various methods for returning seafood processing wastes to the marine environment. The contractor should not rule out this low-cost, environmentally acceptable, disposal alternative.

2, 2, 1, The report does not, but should, address disposal alternatives and potential uses of wastes in Puerto Rico, Hawaii, Guam, and American Samoa. The contractor should either include these areas in the report or explain why they were omitted.

2, 3, 3, As we noted at 2, 2, "the major areas of interest," should have included an assessment of technologies to ". . . facilitate the use of the nutrients in these wastes . . ." when discharged". . . into the marine environment." (See Section 74 of the Clean Water Act.)

4, 1, 1, This sentence should be rewritten to read as follows:

> This report addresses three of the major topic areas relating to the Section 74 Seafood Processing Study:
>
> 1. Return of seafood processing wastes to the marine environment;
> 2. Waste control technology and the costs associated with reducing seafood waste discharges; and
> 3. Utilization and disposal of materials accumulated through the application of waste control technologies.

4, 3, 1, The statement is made that the tuna processing segment and modern fish meal plants (with solubles) should be assed separately from the rest of the seafood processing industry with respect to waste control and utilization because they "best demonstrate the philosophy of total utilization of raw materials." We concur that the tuna processing industry has installed the highest level of waste-water treatment employed by the seafood processing industry and that they do indeed utilize as much of the raw material as possible. However, the contractor's emphasis should be placed not on the philosophy of total utilization but on the differences between the tuna processing industry and the other subcategories, such as length of season, volume of raw product processed, plant size, ability to hire professional environmental staff, potential of waste materials for manufacture of by-products, proximity of processing plants to by-product (reduction) plants, processing equipment employed, and degree of treatment required on a case-by-case basis in order to protect receiving water quality. In other words, we concur that the tuna and fish meal processing industries should be assessed separately from the rest of the seafood processing industry but we do not agree that it should be based upon a philosophy of total utilization; rather, it should be based upon the fundamentally different characteristics of the industries. We recommend the report be rewritten to differentiate clearly between these two vastly different segments of the seafood processing industry.

5, 2, We recommend that this paragraph be rewritten as follows:

> Seafood processors comprising the remaining segments of the industry are generally small, seasonal operations, often family owned, which have complied with the existing EPA effluent guidelines.

We strongly disagree with the statement that most of these plants operate antiquated processing equipment and demonstrate limited and unsophisticated waste management techniques. The equipment is not antiquated. If a new plant were to be constructed today, equipment similar to that currently employed would be installed. We strongly believe that the waste management techniques currently employed are adequate to prevent degradation of marine wasters at most locations.

5, 3, We recommend that this paragraph be deleted from the report. The first sentence states that the significance of waste loads generated by the seafood processors has been recognized by EPA during its previous investigations; however, the "significance" is not identified, nor are the previous investigations referenced which have been "recognized" by EPA. The second sentence states that the impact of waste discharges from this industry has been documented at several sites; however, no references are cited and the word "impact" is not explained. Waste discharges can have both beneficial and adverse impacts. References should be provided showing both types of impact. The third sentence of this paragraph could remain.

6, 1, 5, The applicability of this sentence to the report is questioned. The barometric condenser water and condensate are not wastewaters, do not require treatment, and are discharged directly to the receiving wasters. It is not comingled with processing wastewaters. The statement is made that unloading water is usually combined with "another concentrated waste stream." This other concentrated waste stream should be identified.

6, 1, 3, The sentence beginning with the words "fish meal" should begin a new paragraph.

6, 2, 1, The term "at less progressive canneries" should be deleted.

6, 2, 3, The seafood processing industry disagrees with the statement that biological treatment systems should be considered. Just because the tuna industry processes essentially the year around is no basis to imply that biological treatment is an appropriate treatment alternative. In our view a Federal requirement for application of biological treatment for any segment of the seafood processing industry would result in "treatment for treatment's sake."

6, 3, 1, The term "minor improvements, such as . . . " should be deleted. The sentence would then read: Containing spills and reducing water use during washdown are pertinent to modern fish meal facilities.

6, 3, 3, The sentence beginning with the word facilities should begin a new paragraph. Also, the period at the end of this sentence should be changed to a semicolon and we recommend that the following be added: however, the feasibility of installing solubles plants must be evaluated on a plant-by-plant basis.

7, 1, This paragraph should be rewritten. The contractor should recognize the discharge of seafood processing wastes into the marine environment as a waste disposal alternative. Instead, the paragraph implies that all seafood processors should undertake extensive in-plant modification programs to control waster use and minimize contact of processing water with the raw material and wastes. Such in-plant modifications should only be considered where local water quality conditions indicate that complex wastewater treatment technologies may be required. We disagree with the implication of this paragraph that improved in-plant operations to control water use will result in reduced waste loadings and also provide improved potential for more complete raw material utilization. The manufacturing of secondary products for human consumption and by-products for animal feed and other purposes such as production of chitin/chitosan are business ventures in themselves. Just because a seafood processor upgrades in-plant operations, does a "better" job of controlling water use, and handles the raw material and resulting wastes in a "better" manner does not mean that acceptable markets can be found for by-products made from these wastes. We recommend that this paragraph be rewritten in the following manner:

> Processing activities vary among the remaining segments of the seafood processing industry. Those segments able to utilize grinding or screening need not concern themselves with capital intensive in-plant changes to reduce the quantities of waste generated or the amounts of water used. However, for those plants where more complex treatment may be required, individual plants should investigate in-plant modifications to control water use and minimize water contact with the raw material and wastes. Reduced water consumption could result in a reduction in the size of the wastewater treatment system ultimately constructed or in the size of barges needed. It is important to recognize that reduced water consumption usually does not result in reduced waste loadings. Rather, when water is recycled and used only where necessary, the waste materials become concentrated in the liquid waste streams.

7, 2, 1, We concur that there is a concern for environmental protection on the part of the seafood processing industry. However, we do not agree that there is a growing concern for improved environmental protection. On the contrary, the seafood processing industry believes that the environment is generally adequately protected by the wastewater treatment technologies current in place. Consequently, we do not agree that there are current economic incentives for more effective in-plant waste management on the part of the industry.

7, 2, 2, This sentence should be rewritten as follows:

> Seasonal food processors generally have only screening technology in place. This technology is adequate at most locations in order to protect receiving water quality.

The phrase "with the exception of the major tuna processors and modern fish meal plants," should be deleted from this sentence because it is redundant. This part of the report refers only to "other industry segments."

7, 2, 3, This sentence should be deleted. We do not agree that physical-chemical treatment methods (such as DAF) should be considered or emphasized for seasonal seafood processing plants.

8, 1, 1, We disagree with the statement that most seasonal seafood processing plants can economically afford to upgrade their wastewater practices. The contractor has assumed that seasonal seafood processing plants in the contiguous states will be able to install, maintain, and operate the complex wastewater treatment system, dissolved air flotation and remain in business. We disagree. The imposition of controls requiring technology greater than screening will result in widespread plant closures and industry dislocations. Even the EPA Economic Impact Documents predict that many plant closures would result from the application of this technology (see Tables VI-7 and VI-8 of EPA Economic Impact Documents Nos. 230/2-74-025 and 230/2-75-047, respectively).

8, 2, 1, The manual operations discussed in this sentence should be identified. Are they hand-filleting of bottom fish, butchering of salmon, or crab picking?

8, 2, 2, The word "can" is inappropriate. This sentence should be modified to read as follows:

> Some plants may be able to afford higher levels of treatment where necessary to achieve locally derived water quality standards.

8, 2, 3, The catfish sentence should begin a new paragraph.

8, 3, 1, We disagree that all of the waste management concepts and treatment technologies discussed in this report have been proven by model plants. Many of the technologies may have been tried by pilot plants but they certainly have not been proven or demonstrated to be widely applicable to the entire industry. Particularly, technologies such as biological treatment and reverse osmosis have not been proven applicable to the seafood processing industry. This sentence should be rewritten to read as follows:

> Some of the waste management concepts and wastewater treatment technologies discussed herein have already been tried by model plants within various segments of the seafood industry.

8, 3, 2, We concur that many of the technologies considered in this report have been applied successfully by other food industries; however, this does not mean that these technologies should be considered applicable to the seafood processing industry.

8, 3, 3, The contractor states that the levels of technology included in the report are "proposed" for the various industry segments. We were not aware that this report was intended to propose levels of technology.

8, 3, 4, We disagree that the levels of technology "proposed" by the contractor reflect the special nature of the seafood processing industry. This sentence contradicts the sentence at 8, 3, 2, which states that the technologies considered applicable have been applied successfully by "related food industry in the United States and abroad." We concur that the contractor has applied technologies utilized by other food industries to the seafood processing industry; however, the technologies applied by other food industries do not "reflect the special nature of the seafood industry," particularly its processing operations and most importantly, its geographic location. If the contractor did take into consideration the geographical location, the report would contain a discussion of means of dispersing seafood processing wastes into marine waters.

8, 3, 3, The industry disagrees that the contractor has adequately examined the effectiveness and associated costs of the "proposed" technologies. In order to do this, the contractor would have to examine the costs of achieving particular pollutant reductions against the economic impact that such costs would have on processing plants, and the contractor would have to examine the effect of pollutant reduction discharges on receiving wasters. The contractor has taken neither of these steps.

9 and 10, Table 1, No references are provided for the sources of the costs presented. Accordingly, we cannot comment on their validity; however, the biological systems for tuna apparently do not include the additional cost of DAF construction, operation and maintenance. DAF would probably be required for efficient operation.

11, 1, 1, We question the statement that wastes generated by seafood processors have "some value." Those residuals that are already utilized to manufacture by-product are not wastes. The residuals that remain after by-product manufacture are wastes and have "no value."

11, 1, 5, The contractor has concluded that existing wastewater treatment techniques will not be allowed in the future. Also, the contractor has concluded that the discharge of seafood processing wastes adversely impact water quality. Both of these conclusions are improper as well as incorrect. Accordingly, this sentence should be deleted from the report.

11, 2, 1, The word "sophisticated" should be replaced with the word "complex."

Pages 11 through 15 discuss seafood waste utilization and disposal techniques. We recommend that this section be divided into two sections as was done in the section on Waste Control and Treatment, pages 5 through 10. The first section would be on Tuna and Modern Fish Meal Processing plants, and the second section would be on Other Industry Segments. The rationale for this recommendation is that the seafood waste utilization and disposal alternatives are different for these two segments of the industry.

11, 3, 2, The word "modern" should be replaced with the word "some."

11, 3, 3, We disagree with the statement that the addition of solubles to fish meal improves the quality of the product. Also, the words "as with the tuna canners' approach," should be deleted, because the addition of solubles to fish meal is not unique to the tuna processing industry.

12, 1, 3, This sentence should be revised to read as follows:

> Investigations are required to establish the feasibility of producing an animal feed additive, fertilizer from float, or disposal at sea.

12, 2, 1, We recommend that this sentence be revised to read as follows:

> For the remaining segments of the industry, where waste utilization is desirable, improved in-plant waste management may be necessary.

We disagree with the tone of this sentence which implies that existing waste management techniques are not "enlightened."

12, 2, 2, The words "and utilized" should be deleted from this sentence. Just because you are able to collect the solids does not mean that you will be able to utilize them. Also, the words "and the solids generated by biological wastewater treatment systems" should be deleted. There is no current nationally approved method by which these solids can be utilized for the production of any by-product use.

12, 2, 3, This sentence should be rewritten as follows:

> Once collected, these solids have potential for reuse as animal feed, fertilizers, and other useful materials, depending on the species processed, processing steps employed, chemicals used, and the granting of approval for such use by the Food and Drug Administration.

14, 1, 1, The phrase "a more interesting" should be replaced with the word "another."

14, 1, 2, We recommend that the first part of this sentence be revised to read as follows: "These natural polymers have potential for a wide range of applications,"

15, 1, 1, The other study participants should be identified.

15, 1, 3, We recommend that the first part of this sentence be revised to read as follows: Other theoretical by-product alternatives which have yet to be demonstrated feasible include . . .

15, 2, 2, We recommend that a period be placed at the end of the word "accomplish" and the remainder of the sentence deleted. Most food processors do not consider barging costs to be "reasonable" and they do not believe that their current discharges adversely impact near-shore waters.

15, 3, 2, We recommend that this sentence be revised to read as follows:

> By-product production may be a solution for disposal of gross and screened solids at some locations.

The contractor has utilized the term "by-product recovery." By-products are produced, wastes are recovered. Generally, by-product production results in a negative cash flow and therefore is not an "attractive solution."

17, 1, 1, The word "contaminated" should be replaced by the words "process contact."

17, 2, 1, This sentence should be revised to read as follows:

> Concern for the environmental effects of wastewaters discharged to receiving waters by municipal and industrial point sources has led the United States Congress to provide EPA with the authority to issue guidelines for the cleanup and regulation of the discharges.

The contractor has erroneously charged the nation's seafood processing industry with being the reason for enactment of the 1972 amendments to the Water Pollution Control Act. This statement may reflect the attitude of the contractor toward the industry; however, the House passed version of the 1972 amendments exempted seafood processing wastes from the definition of "pollutant" (see Committee Print, Serial Number 92-1, Legislative History of the Water Pollution Control Act Amendments of 1972, Volume I, January, 1973, page 1068).

17, 2, 2, We recommend that this sentence be revised to read as follows:

> Federal regulations, referred to as secondary treatment and effluent limitations guidelines, have specified the maximum amount of waste materials for pollutants which can be discharged by municipalities and industrial point sources.

17, 2, 1, We recommend that this sentence be revised to read as follows:

> The seafood processing industry has made a considerable effort and has generally achieved compliance with applicable federal and local waster pollution control requirements.

It is inappropriate to compare wastewater treatment techniques employed in other food processing industries to seasonal seafood processing plants. While it is a fact that other food processing industries do employ more complex wastewater treatment methods than seasonal seafood processors do, there are valid reasons for the implementation of different technologies. For instance, most other food processing industries are operated year round, discharge into inland waters, have greater economic stability, are usually larger in size, and have control over their raw material supply. If the contractor wishes to compare the wastewater treatment techniques of the seafood processing industry with other food processing industries, the inherent differences between the two industries should be clearly noted.

17, 3, 2, We recommend that this sentence be rewritten as follows:

> While the Agency has required other food processors such as meat packers and poultry processors to adopt more complex and costly technology than those implemented by the seafood processing industry, there are valid reasons for the different technologies. Among these differences are year-round operations, point of discharge (ocean vs. inland waters), economic capability, plant size, and control over raw material supply.

17, 4, 4, The term "often antiquated" should be deleted and replaced with the following: "Adequate to comply with existing federal and state requirements."

17, 4, 5, The remaining sentences of this paragraph should be deleted or placed in a separate section discussing the tuna and fish meal processing industries.

18, 1, 3, The words "or no" should be inserted between the words "limited" and "land."

18, 2, 1, This sentence should be revised to read as follows:

> Technologies for reducing the discharge of solid and liquid waste from seafood processing plants can be segregated into two categories.

18, 3, 3, While the statement is correct, the contractor should emphasize that decreased water usage is only useful in the design stage of the consideration of wastewater treatment alternatives. Once the treatment facility has been constructed there may not be any tangible results of water conservation practices. For example, the operation and maintenance costs for dissolved air flotation of tuna processing waste is about 80% for the suspended solids loading and 20% for water. Consequently, even if the amount of water were to be cut in half, little savings in the operation and maintenance costs would be achieved.

19, 1, 1, The words "foreign matter or pollutant" should be replaced with the words "volumes of wastes."

19, 2, 3, This sentence states that the "model" plant represents "existing plants." After having made an extensive analysis of information contained in the development document, we question the contrator's statement. The sentence provides no source for its reference to these existing plants. We are of the view that the contractor has erred and that these "existing plants" do not in fact exist.

19, 3, 1, This sentence should be revised to read as follows:

> The model plants generate less wastewater than other plants which have not installed equivalent in-plant management practices, reflecting the use of intensive water saving techniques of most model plants.

The contractor has improperly concluded that plants using more water than the model plants have "poor" in-plant management practices.

19, 4, 1, This sentence should be deleted. Where are the references to show that comprehensive water and waste management programs can produce "economic benefits" particularly for plants which already have adequate waste disposal facilities in place to protect receiving waters. Also, what are the "traditional practices" that seafood processors must break away from?

21, 2, 1, The word "principal" should be deleted from this sentence.

21, 2, 3, The word "simple" should be deleted from this sentence.

21, 4, 1, The word "pollutants" should be replaced with the word "wastes."

21, 4, 2, The words "extremely contaminated" should be replaced with the words "heavily loaded."

22, 1, 1, The words "more sophisticated" should be replaced with the word "other."

22, 1, 2, The word "contaminated" should be replaced with the word "concentrated."

24, 1, 5, The contractor should identify the specific solid wastes that are believed to be utilizable and the "valuable commodities" that can be made from these wastes should also be identified.

24, 3, 1, We recommend that this sentence be rewritten as follows:

> Based on existing wastewater treatment requirements, currently employed in-plant control measures are effective in managing seafood processing wastes.

The contractor has erroneously concluded that existing in-plant control measures in seafood processing plants are "lacking."

24, 3, 2, We recommend that this statement be revised to read as follows:

> The seafood processing industry is reluctant to adopt complex waste management techniques for two reasons: (1) the maintenance of traditional practices and conceptions which are based upon the rationale of "returning to the sea what came from the sea;" and (2) the end-of-pipe technology currently required by state and federal governments is adequate to protect receiving waters at most locations.

Consequently, there is no need for the seafood processing industry to emphasize complex procedures or technologies for reducing raw waste loads.

27, 2, 1, The contractor is implying that EPA should increase the level of control imposed on seafood processing plants and that no segment of the industry will have any problem with compliance. We disagree strongly with the tone of this sentence and recommend that it be deleted. The contractor has made no economic impact analysis to determine if in fact all segments of the industry can adopt more effective in-plant water and waste management practices.

27, 2, 2, Again, the contractor has prejudged the report and has concluded that discharges to the marine environment should be eliminated. We recommend that this sentence also be deleted from the report.

27, 2, 2, We recommend that this sentence be rewritten as follows:

> Once a plant determines that in-plant modifications are necessary, the elimination of flumes for raw material, finished product, and waste conveyance can be installed where economically justified.

27, 2, 4, This sentence is repetitive and can be deleted.

27, 2, 5, We recommend that this sentence be rewritten as follows:

> In-plant measures and process modifications can play an important role in minimizing economic impacts on plants which decide to implement costly end-of-pipe treatment technology.

28, 2, 1, We recommend that this sentence be rewritten as follows:

> The levels of treatment employed by seafood processors are adequate to comply with existing federal and state requirements.

28, 2, 2, We recommend that the word "sophisticated" be replaced with the word "complex."

28, 2, 3, We recommend the following new sentence be added at the end of the sentence ending in the words "marine environment."

> However, the application of such technology is unnecessary in most cases for the protection of receiving waters.

28, 2, 4, We recommend that this sentence be rewritten as follows:

> End-of-pipe treatment approaches available to the seafood processing industry are described in the Development Documents. The only information presented here is new information that was not discussed in the Development Documents.

We do not believe that there is a need to repeat in this report information that is already available in the Development Documents. Only that information that is new or updated should be presented here.

28, As noted previously, the contractor has made no reference to techniques for disposing of seafood processing wastes in the marine environment. Such techniques should be discussed at this point in the report.

36, 2, 1, We recommend that this sentence be rewritten as follows:

> Biological processes do not comprise a common technology for the treatment of effluents generated by the seafood processing industry; however, these processes are common for treatment of municipal wastewaters and effluents by some other segments of the food processing industry.

38, 1, 5, We question the statement that the extended aeration process has been demonstrated on seafood processing wastes. Rather, we are of the view that it has been attempted on pilot plants but not full scale levels.

39, 1, 8, We recommend that the word "demonstrated" be replaced with the word "attempted."

42, 3, 5, We disagree with the implication that just because tuna canneries are continuously operated that biological treatment systems are applicable for them.

42, 3, 6, This sentence should be deleted. The fact that vessels travel thousands of miles has no effect on this report.

43, 2, A section should be added to the discussion of physical-chemical treatment techniques on operator training requirements. How many people are required, what should be their qualifications, and how much should they be paid? The contractor notes at 57, 2, 2, that skilled labor is restrictive in Alaska. Why isn't it also restrictive to seasonal processing plants in the contiguous states?

47, 2, 3, We recommend that this sentence be revised to read as follows:

> A full scale application has been limited to a trout processing plant in Idaho.

The unit at Treminal Island, California, has not been operated at full-scale.

47, 2, 4, We recommend that this sentence be revised to read as follows:

In Russia, a flotation cell with mechanically induced air has been treating fish processing effluent.

48, 1, 2, We recommend that this sentence be revised to read as follows:

Some private testing has been performed on tuna cannery effluents.

48, 2, 2, We recommend that the words "need to combine" be replaced with the words "possibility of combining."

48, 2, 4, We recommend that this sentence be revised to read as follows:

However, an advantage noted for the hybrid system is the possible concentration of the floated material within the unit to a higher than normal level.

48, 3, 1, We recommend that this sentence be revised to read as follows:

It is apparent that electroflotation has not been demonstrated sufficiently to gain acceptance by the seafood processing industry.

48, 4, 2, We recommend that the word "pollutant" be replaced with the word "waste."

49, 2, 2, We recommend that this sentence be rewritten as follows:

However, these advanced systems are seldom applicable to seafood processing.

49, 3, 5, We recommend that the word "can" be replaced with the word "may."

52, 2, 3 and 4, We recommend that these two sentences be deleted.

52, 2, We recommended that the following sentence be added at the end of this paragraph:

Several of the noted methods have been tried by the tuna industry and have not been proven feasible.

53, 2, 1, In item 3, we recommend that the words "seep" and "into" be deleted.

53, 3, 3, We recommend that the word "would" be replaced by the word "can".

54, 3, 3, We recommend that this sentence be revised to read as follows:

The most basic and prevalent end-of-pipe treatments have been grinding with direct discharge and solid separation by screening.

55, Table 5, references for the data shown in this table should be provided.

56, Table 6, references for the data in this table should be provided.

56, 2, 2, We recommend that this sentence be rewritten as follows:

> The usefulness of dissolved air flotation systems for removal of suspended solids and oil and grease has been demonstrated on a full-scale level at several tuna canneries within the United States and its territories.

56, 2, 3, We recommend that this sentence be deleted and replaced with the following sentence:

> However, attainment of higher removal efficiencies has been proved economically unsound.

56, 3, 4, The term "optimized DAF systems" should be defined. Also, we recommend that this sentence be revised to read as follows:

> For the other segments of the seafood processing industry, the capabilities of optimized DAF systems have been demonstrated in limited tests conducted in the United States and Canada utilizing federal grants.

57, 3, A new sentence is recommended to be added between the words "industry" and "Table 7" to read as follows:

> However, practical and economically feasible application of this technology to commercial processors in the United States has not been demonstrated for most species listed.

57, Table 7, references should be provided for the data in this table. Also, the industry representative from the Maine Sardine Council suggests that the plant size for sardine and herring fillet plants be increased to 60 and 120 tons per day, respectively; the total daily flow for these plants should be increased to 0.1 and 0.2 million gallons per day, respectively, and the capital and O&M costs for each of these should be increased by at least 50%. Also, the American Shrimp Canners Association reports that "there is a discrepancy in the Southern, non-breaded shrimp category. The plant size and total daily flow do not conform to the experience and studies made by ASCA for DAF systems operations." Accordingly, the projected costs are in error. For additional information contact Mr. A. J. Szabo (318/232-5182) or see the following report: Dissolved Air Flotation Treatment of Gulf Shrimp Cannery Wastewater, June 1978, EPA Project No. S803338 01-1.

59, 1, 1, The words "are allowed to" should be deleted.

59, 1, 3, The words "then allowed to escape into" should be replaced with the word "entered."

59, 1, 5, The words "the more" should be deleted.

59, 2, 2, This sentence should be rewritten as follows:

Historically, comprehensive in-plant water and waste management practices have not been needed generally in this industry.

60, 1, 3, This sentence should be rewritten as follows:

Relatively simple management practices are available to approach recovery of the raw material; however, these practices are not widely employed by the industry due to economic considerations, market limitations, and regulatory constraints.

It is generally "simple" to recover raw material; however, utilization of recovered materials is not "simple" as implied by the contractor.

60, 3, 1, The word "sophisticated" should be replaced with the word "complex."

60, 3, 2, The beginning of this sentence should be revised to read as follows:

Most common are grinding and direct discharge, or simple solids separation systems . . .

60, 3, 4, The word "manufacturing" should be substituted for the word "manufacture."

61, 1, 1, The word "pollutant" should be replaced with the word "waste."

62, 1, 1, The word "care" should be replaced with the word "caution."

62, 2, 2 and 3, The contractor should include a discussion of the likely impact of EPA's Solid Waste Disposal Criteria (February 6, 1978 Federal Register), and EPA's proposed Hazardous Substances Regulations (December 18, 1978 Federal Register) on the disposal of DAF sludges containing "salt" and "significant concentrations of aluminum." Will disposal sites continue to be available for deposit of these wastes?

62, 3, Throughout Section B, the contractor in discussing the current secondary and by-product production methods suggests that the industry does not look for innovative ways to produce and market waste materials. On the contrary, the industry has tried a number of techniques which have not proven feasible. The contractor has reported on two of these attempts at 68, 3 and 74, 3, 2. Yet, these trial methods which have failed continue to appear in the report as methods which are practical and the industry is criticized for not implementing them.

We recommend that the by-product production and utilization methods presented in Section B be discussed in the following categories:

1. Successful commercial ventures;

2. Attempted commercial ventures;

3. Pilot projects; and

4. Theoretical considerations.

Such categorization is essential to full understanding and discussion of by-product production and marketing.

63, 2, 6, The words "can also be" should be substituted with the words "hold the possibility of being."

65, 2, 5, It is a fact, not an "indication" that additional investigations are necessary to gain FDA approval for the use of chitosan as a food (or feed) additive. The contractor should provide in the report a thorough analysis of the requirements and costs for obtaining FDA clearance.

65, 3, 2, The word "readily" should be deleted.

67, 1, 4, The words "less than one tenth" should be replaced with the words "approximately 3% of."

67, 2, 1, The word "than" should be replaced with the word "from."

68, 2, 3, This sentence should be deleted. Water quality considerations were not part of the Administrator's procedures for designating these non-remote areas. The Clean Water Act does not currently provide for consideration of water quality factors in the establishment of effluent guidelines. The purpose of the Section 74 Seafood Study was for EPA to prepare a report for Congress' consideration so it could consider whether or not to amend the law to allow water quality factors to be considered in the determination of effluent limitations for seafood processing plants.

68, 2, 4, The words "people demanding lower wages" should be substituted with the word "workers."

68, 3, 1, This sentence should be revised to read as follows:

> Two non-remote areas --Kodiak and Petersburg -- have reduction facilities which convert fish processing wastes to by-products.

Seward is not a remote area.

68, 3, 3, The following new sentence should be inserted after the words "immediate area":

> It was constructed to serve as a waste disposal facility for the processors and is subsidized as such by the processors.

68, 3, 4, This sentence should be revised to read as follows:

> The facility in Petersburg was intended to be economically self-sufficient in producing fish meal and oil from whole fish and processing wastes generated in its geographical area.

69, 1, The remainder of this paragraph after the words "geographical area" should be revised to read as follows:

> However, the facility has not been operated at full capacity on an annual basis due to the limited availability of raw materials. This limited availability does not result from the waste management practices of the area plants. It results from the lack of a continuous processing season. Because the Petersburg reduction plant has excess capacity, it will generally accept processing wastes transported from outside the immediate area. This plant has received and processed wastes from processors located more than 100 miles away on a trial basis, but this did not prove economically feasible and has been discontinued.

69, 2, 2, The remainder of this paragraph after the word "procedure" should be revised to read as follows:

> Alaskan salmon canneries, on a trial basis, have collected, packaged, and frozen salmon heads for shipment to Seattle pet food operations. This practice did not prove economically feasible and it has been discontinued.

69, 2, 3 and 4, These sentences should be deleted.

70, 2, This paragraph should be revised to read as follows:

> Solids handling and disposal practices which have been adopted by most segments of the seafood processing industry are practical but unsophisticated. With the exception of the tuna and fish meal processing segments, there has been limited implementation of in-plant waste management practices or secondary by-product manufacturing. Most changes in-plant water and waste management have resulted from either a serious pollution problem or normal economic advantages derived from more complete raw material utilization.

70, 3, 1, This sentence should be deleted. The contractor has improperly concluded that the existing wastewater practices employed by the seafood processing industry are inadequate in order to protect receiving waters.

70, 3, 2, The words "The most economical" should be replaced by the words "If necessary."

70, 3, 4, The words "readily yield" should be replaced by the words "result in."

71, 1, 1, The words "create the need" should be replaced by the words "create a need." The word "identifying" should be deleted; and the words "options for" should be replaced by the words "options in."

71, 1, 2, The words "a number of" should be replaced by the word "some."

71, 1, item 4, the term "ultimate disposal methods" should be replaced by the term "other disposal methods."

72, 2, 4, The word "readily" should be deleted.

72, 3, 3, This sentence should be deleted because the production of meal is not a "secondary product" intended for human consumption.

73, 3, 1, In item 2, the word "can" should be substituted by the word "may."

74, 2, 3, The words "37 to 60%" should be deleted.

74, 2, 4, This sentence should be deleted. Conventional filleting techniques do not yield secondary products. They yield primary product.

74, 2, 7, The word "can" should be substituted by the word "may."

74, 3, 2 and 3, These sentences should be deleted or at least modified to accurately reflect that this facility is no longer producing this product because of economics.

74, 3, 4, The word "bottom fish" should be replaced by the words "only fin fish."

74, 3, 5, The word "can" should be replaced with the word "may."

76, 2, 2, The word "scraps" should be replaced by the words "blood meats" and the words "less appealing" should be replaced by the words "off-color."

76, 3, A new sentence should be added at the end of this paragraph as follows:

This has proved feasible in only a limited number of non-Alaskan plants.

80, 1, The contractor should discuss the additional costs involved in handling, shipping, and storing the liquid fish silage in comparison to dried meal. Also, what are the economics of drying silage compared to the normal fish meal process? What benefits would result from drying fish silage? Why not make fish meal in the first place?

81, 1, In the first item, the contractor should identify the aquaculture operations and should identify which species would be utilized to achieve the desired pigmentation.

83, 1, 2, The beginning of this sentence should be modified to read as follows: "Suspended solids, oil and grease which are attached to . . ."

83, 2, 2, We believe the 20% figure to be in error; shouldn't this figure be 10% as shown on page 61.

83, 3, 1, We recommend that this sentence be revised to read as follows:

> The removal of colloidal constituents at times can be aided by adjusting the pH to the isoelectric point of fish protein (pH 4.5 to 5.0); however, pH adjustment to this low level requires that the equipment be designed for resistence to acid corrosion. Also, the pH must be readjusted to between 6.0 and 9.0 prior to discharge to receiving water.

84, 1, The following qualifier should be added at the end of the last sentence of this paragraph: "float; however, FDA has not approved any such chemicals for food or feed use as of the date of this report." The contractor should explore with FDA if any companies have submitted petitions for food or feed additive tolerances for any of the chemicals used in DAF treatment. The results of this exploration should be included in this report.

85, 3, 4, The meat packer should be identified with a reference.

85, 3, 5, A reference should also be provided for the production of methane from the DAF float.

86, 1, 1, A reference should be provided for the Colorado brewery which utilizes chemical treatment and DAF to thicken sludge from a secondary wastewater treatment plant.

86, 1, 2, The following qualifier should be added at the end of this sentence:

> "; but only in the State of Colorado because FDA has not approved it for use in interstate commerce."

The contractor has left the reader with the impression that the marketing of such a product is a very simple procedure. As stated previously in these comments, the contractor should provide a full discussion of the problems involved in obtaining FDA clearance for the production and marketing of such materials.

86, 3, 1, We recommend that this sentence be deleted. The contractor provides no references for his conclusion on foreign seafood processors.

86, 3, 2, We recommend that this sentence be revised to read as follows:

> In the United States, continuous research is being conducted by the tuna canners on the use of DAF float; however, at the present time, there are no approved markets for DAF float. Consequently, the domestic processors which employ DAF treatment generally dispose of it in land fills.

86, 4, 1, References should be provided.

87, 1, 2, The word "might" should be inserted between the words "methods" and "include", at both places in this sentence.

88, 1, 3, The words "is no greater than the total plant uptake" should be substituted by the words "is not in excess of the system's ability to assimilate it."

89, 2, 1, This sentence should be deleted. The contractor has improperly concluded that seafood processing plants must install dissolved air flotation facilities to comply with future wastewater treatment requirements.

89, 2, 2, The words "by EPA" should be inserted between the words "identified" and "as."

89, 2, 3, The word "hopefully" should be deleted.

90, 1, This paragraph should be deleted as the potential worldwide protein shortage has no impact on wastewater treatment requirements for seafood processing plants. The entire paragraph is based on conclusions of the contractor without any reference to the volumes of food needed to solve the world's protein shortage or how much of this need seafood processing wastes could help alleviate, if they could miraculously be converted from a waste to a food.

90, 1, 3, If the contractor wishes to discuss overseas operations, references should be provided and the geographic, climatic, size of plant, length of season, government assistance programs, and other differences between the U. S. and the others should be included in the discussion.

92, 2, This paragraph is repetitive of previous information and should be deleted.

92, 2, 2, Does the "approved water treatment polymer" have approval from FDA as a food or feed additive?

93, 2, 3, The word "much" should be replaced by the word "some" and a period should be added after the word "environment". The term "as waste material" should be deleted.

94, 2, 4, A comma should be added after the word "waste disposal" and the term "high-profit" should be deleted.

114, 1, 4, The words "some of" should be inserted between the word "At" and the word "the." Also, the words "highly contaminated" should be deleted.

* * * * *

APPENDIX H

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NFPA National Food Processors Association
1133 Twentieth Street N.W., Washington, D.C. 20036
Telephone 202/331-5900

Economics and Statistics
Dr. Lawrence Van Meir
Director
202/331-5997

April 16, 1979

Sammy K. Ng
Office of Analysis and Evaluation (WH-586)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Regarding: Comments on the March 1979 Draft Report titled Marketing Feasibility Study of Seafood Waste Reduction in Alaska, prepared for EPA by the Development Planning and Research Associates, Inc., Manhattan, Kansas.

Dear Mr. Ng:

The National Food Processors Association, formerly the National Canners Association, is a nonprofit trade association representing approximately 650 companies who pack about 90 percent of the total United States production of canned foods for human consumption. The seafood processing members of NFPA are pleased to have an opportunity to provide comments on the above draft contractor report to EPA on the Section 74 Seafood Study. Our comments are provided on an individual page, paragraph and sentence number basis.

Page I-5, 3, 1. The statement is made that crab and shrimp meal are "low value." What is meant by the term "low value"? What is the value in relation to salmon meal?

Page I-5, 3, 3, The statement is made that "if all of the wastes available were processed as presented in Chapter II, Alaska could account for nearly 10 percent of the U.S. production." The part of the statement "all of the waste available" should be explained. Are these the wastes found in Petersburg, Seward and Kodiak; or are they all of the wastes that may be available in Alaska?

Page I-5, 1, 5, It is implied that the low capacity of utilization of reduction plants, other than at Kodiak, is due to seafood processing plants not collecting their wastes for the reduction plants. If it were economically feasible to collect these wastes for processing, would not the seafood processing plants already be doing it?. This study has left out this most important point, i.e., it is not economically feasible to collect wastes from other plants to process. Unfortunately, the contractor has not included a consideration of such costs in its analyses. Another reason for the low percentage utilization is that the reduction plants are large in relation to the available recoverable wastes. This will always be a problem at most Alaskan points. In order to handle peak seasonal flows, the plant will have substantial excess capacity for the balance of the year.

Page I-10, 2, 1, The report does not analyze the supply and demand factors underlying price elasticity of demand for fish and shellfish by-products. The revenue estimates for the model meal plants in Alaska are based on assumed prices of $360 per ton for salmon meal and $100 per ton shellfish meal, the actual prices at Seattle in September of 1978 (Page I-15, 3). However, fish and shellfish meal was only available in extremely limited quantities when these prices were obtained. Is it reasonable to expect this price to hold if production of meal in Alaska jumps to 13.4 million tons of salmon meal and 31.8 million tons of shellfish meal? What would be the economic effect on the NPV of the plants if the price were to drop considerably?

Page I-13, 3,1, Although historical data on prices for Alaskan fish meal and oil are not available in published form, good factual data on price and volume could have been obtained from Pacific Northwest fish meal dealers or from Bio-Dry in Kodiak.

Page I-15, 1,1, Reference is made to "... a regression technique analysis utilizing supply and demand factors show that current prices are fairly representative of normal conditions; ...".No information is given on the variables and source of data used in the analysis. At a minimum the regression equation and identification of the variables along with "t" values should be included in the text.

Page I-15, 3, Table, A market analysis should be conducted to determine an estimate of the price elasticity of demand for meal and oil products. To what price levels would these products fall if production in Alaska were to be increased by 50%? 100%? 200%?

Page I-15, 4, 1, What part of potential production of shellfish meal would the entire livestock industry of Alaska (or Washington) use? Does Alaska have available sufficient quantities of other feeds (corn, barley) to utilize significant quantities of shell meal? What percent of the feed requirements can fish meal comprise?

Page II-1, 2, 2, The justification for use of limited and secondary data was, "improbable total cooperation of all processors," and the need to collect data over several years to arrive at complete and accurate data. However, no attempt was made to contact the processors or their associations for available data we would have cooperated fully to assist the contractor had we been contacted. We believe that most of the data sought is already public knowledge and that the contractor should be familiar with the sources (See "Draft Report Industry Structure and Pricing Patterns in Alaskan Seafood Industry" EPA Contract No. 68-01-4630, October 1978).

Page II-2, Table at bottom of page, The recoverable waste as percent of live weight is stated at 35 percent and 20 percent respectively for canned salmon and fresh and frozen salmon. Industry experience is a recoverable waste of 20-25 percent for canned salmon and 12-13 percent for fresh and frozen salmon. Just on the basis of this overestimation of waste, assumed production of salmon meal appears to be overestimated by about 60 percent. Due to the price of salmon meal relative to shellfish meal, the use of more realistic output of salmon meal for the model plants would result in a much lower revenue for the model plants.

A factor that further reduces recoverable waste relative to total waste is the physical removal of water clinging to seafood waste. The water is physically removed to decrease fuel cost in the reduction process. However, in the water removal process fish material is lost.

Similarly for shrimp, recoverable waste falls significantly short of total waste due to loss of body fluids and fine particulate material too fine for screening.

Page II-6, 2, 3, The study points out that in 1976 the three existing plants at Petersburg, Seward and Kodiak had a combined production of less than 20 percent of the pro forma estimates for these plants. In view of this fact, is it not unrealistic to base the analysis on the pro forma data?

Page II-10, 1, 3, The projection of 300 thousand tons of potential fish meal production in Alaska by the year 2000 is absolute speculation and of no meaning to this study.

Page II-14, Table II-7, In an earlier comment it was pointed out that the assumed yield of recoverable waste for salmon was almost 60 percent above industry experience. The total revenues in Table II-7 reflect this upward bias in assumed yield of waste. For example, if industry experience is used as a basis for recoverable waste, the total revenue for Kitchikan would be $245,000 (471 tons of meal and 189 tons of oil). Revenues for the other locations are also overstated.

Page II-14, Table II-7, The revenue projected from crab waste should be decreased to account for the 80 pounds of oil that must be added per ton of crab meal necessary to reduce the dust sufficiently to permit handling, shipping and use of crab meal.

Page II-14, Table II-7, In order to obtain seafood wastes of the magnitude shown in Table 7 for Bristol Bay, it would be necessary to collect wastes from a triangular area 50 miles at the base and approximately 75 miles at the sides. It does not appear that the cost of collecting and transporting this waste to Bristol Bay is included in the cost of operating the reduction plant at Bristol Bay.

Page III-4, 1,3, The sizes of plants provided by the E.C. Jordan Company should be provided in the footnote or in an Appendix.

Page III-4, 5,1, Because of errors in the estimation of recoverable wastes available in Chapter II, these revenues appear to be overstated by 60 percent or more (See our comment about Page II-2, table at bottom of page).

Page III-5, Table III-1, The utilization of capacity for the existing plant at Seward is given as 13 percent. The actual experience of this plant has been a utilization rate of 5-6 percent of capacity. The inability of the plant to operate at a higher rate of utilization is due to the unavailability of an adequate supply of raw waste.

Page III-6, Table III-2, As stated earlier, these revenues are grossly overstated due to overestimation of recoverable waste available.

Page III-7, 4, 1, The investment costs provided by the E.C. Jordan Company should be provided in an Appendix.

Page III-7, 6, 2, The study admits that at some locations, a "floater" type of reduction plant would have to be used due to lack of available land. The study does not identify these sites but assumes for all plants a land cost equal to 10 percent of total investment. Applying this methodology to those sites that would have to resortto floaters results in an overstatement of Net Product Value (which means if net product value is negative it would be negative by a larger amount if more realistic data were used).

A floater type reduction plant is a capital investment -- i.e. a case of substituting capital for land. Generally, the initial cost is greater. Secondly, maintenance costs are encountered in connection with the floating platform that would not be incurred in the case with a land based operation. Finally, the cost of land is considered recoverable and therefore has a significant impact on the NPV computed by the formula used in Chapter IV.

Page III-10, 5, The total investment cost for the reduction plants should be compared to the investment represented by the processing plant. Even a general magnitude, i.e., percentage less than, same as, or percentage greater than would suffice.

Page III-11, Table III-5, Has the energy required to remove process water been considered? This greatly understates the energy required per ton of meal processed. For example, the data available would imply that the plant at Dutch Harbor was expected tooperate at 100 percent efficiency. Since drying equipment is considered to be operating optimally at 66 percent of efficiency, it is likely that fuel costs (at 50¢ a gallon) would be two to three times greater than assumed in this study.

Page III-12, 2, The waste material being sent to the reduction facility is considered to have a zero value (neither a cost nor a credit to the model waste reduction plant). We believe that this assumption is invalid. Expenses are incurred in collecting (screening) and storing the waste and in transporting it to reduction plants. These costs should be estimated and utilized in the analysis. While the collection and storage costs may cancel out when comparing waste reduction and barging disposal alternatives, the costs should be included in order to place in perspective the TOTAL cost for waste disposal that must be incurred by affected seafood processing plants. Transportation costs will not cancel out and should be included.

Page III-13, Table III-6, The labor requirement for the existing plant at Seward is stated as one skilled employee and two unskilled employees per shift. The actual operation of this plant employs three skilled employees and two semiskilled employees per shift in addition to plant management input. This underestimation of labor requirements at the existing Seward plant suggests that labor requirements; and therefore, labor costs for all the model plant sizes in Table III-5 are wrong. Since labor costs for the model plants are seriously understated, the entire analysis of Net Product Values is in serious error.

Page III-15, 5, This paragraph infers that E.C. Jordan has reviewed weather and operating conditions at various processing sites and has concluded that there is only a potential problem at Dutch Harbor for the "relatively small barges that could be towed by power skiffs." Have they gathered port-by-port evidence to support this conclusion? If E.C. Jordan does not have data to support these statements, then they should withdraw their conclusions regarding such barging alternatives. Moreover, because barging operations may have to be carried out several times a day, data on tidal fluctuations is necessary to evaluate this alternative.

Page III-17, Item 1, The distances between plants at the Bristol Bay "location" would preclude operating a barge on a cooperative basis. Consequently costs for barging from Bristol Bay (Table III-8) likely are significantly understated.

Page III-17, Item 2, We are unaware of any company that is willing to build a 25 ton barge capable of containing and dumping seafood wastes for $30,000. The contractor should cite a source for this information.

Page III-17, Item 3, Used seine skiffs might be available for $16,000. New, they cost considerably more.

Page III-17, Item 4, It is assumed that one skilled and one unskilled plant employee would be required for two hours per barging trip with an estimated total labor cost of $70.00 per trip. First, it is not probable that plant employees could be utilized to operate the barges. Barge operators belong to a different union than cannery employees. Accordingly, the costs of operators is greatly underestimated. Additionally, ocean barging of waste can be life-risking during certain weather conditions. Second, we do not believe that any employees could be found who will be willing to operate such barges even in good weather conditions for this sum.

Page III-17, Table at bottom of page, The algebraic signs in table are reversed.

Page III-18, 3, The calculation of costs for Dutch Harbor is based on an erroneous assumption that a tug boat and crew can be hired on a daily basis as needed. It is unrealistic to assume that a tug and crew will be idly standing by for a call when needed. More realistically, the tug and crew would have to be retained on an annual base fee. Consequently, actual costs likely will be significantly greater than assigned to this operation.

Page III-19, Table III-8, Because of the various points made on the preceding pages on barging analysis, these costs are grossly understated in our view.

Page IV-2, 3, 2, This paragraph states that there are only two options available for the disposal of screened solid waste; however, a third alternative which is the central focus of the Section 74 Seafood Study, should be included. This option is discharge of the solid waste directly to receiving waters with minimal treatement. The major policy question that should be under consideration is not whether the industry will barge or go to reduction plants if forced to turn from present procedures to one of these, but rather, what are the consequences and benefits of forcing the industry to depart from present practices. Either barging or reduction will add considerably to the cost of processing fish in Alaska. The data on Dutch Harbor shows that revenue from a reduction plant would not even cover the direct costs let alone any yield on investment. If more realistic data were used for recoverable wastes and costs, all model reduction plants exhibit the same situation i.e., they can only operate a continuing deficit on operating costs.

Page IV-3, 5, 2, It may be true that screening and collection costs will cancel themselves out for either fish meal reduction processes or barging; however, trasportation costs would not be cancelled. There would be an extra cost of transportation from the seafood processing plant to the reduction facility. This cost should be factored into Item 3 on this page. Item 3 should have a new litle Screening, Collection and Transportation Costs.

Page IV-5, 5, A company that has costs sunk in capital equipment will tend to use that capital as long as it can cover variable costs and recover anything towards the fixed costs. However, it is entirely a different situation to force the company to use the facility at an output which would greatly increase its total loss. A more realistic analysis of the existing plants would be their NPV's at different levels of output within the existing plant. Adjusting the revenue and labor cost for the data given indicates the existing plant at Seward would have an annual revenue of $140,000 less than direct costs. The more processed the greater the loss under this situation.

Page IV-6, Table IV-1, An equity cost of 15 percent is used for the base case analysis. It is naive to believe that equity costs are 15%, given the nature of the investment, the existing investment climate, and interest rates between 10 and 14%. At best, that would provide debt coverage of only 2 to 3 times. Such coverage would not be acceptable.

Page IV-7, Table IV-2, This table presents sensitivity analyses for 6 variables that will impact the Net Present Value of the model plants. However, the sensitivity analyses ignores several important variations to the assumptions underlying the "base case," namely.

1. A decrease in the price of fish and shellfish meals as output increase.
2. A reduction in raw wastes to be processed because the present study has grossly overestimated recoverable raw waste quantities.
3. An increase in costs due to various under estimates of costs.
4. A cost of equity greater than 15 percent particularly in view of industry experience and inherent risks in Alaska.

Page VI-1, Wherever possible, the specific variances noted in Chapter VI should be incorporated into the other chapters at the appropriate point either as an explanatory sentence or a footnote. It is unfortunate but true that many reviewers and users of technical reports do not read past the text and often overlook the "Limits of the Analysis"

We appreciate this opportunity to submit these comments on behalf of our seafood processing members.

Sincerely,

Lawrence W. Van Meir

Lawrence W. Van Meir

cc: Cal Dysinger, EPA
Dave Jordening, DPRA
Effluent Guidelines Subcommittee for Seafoods